The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
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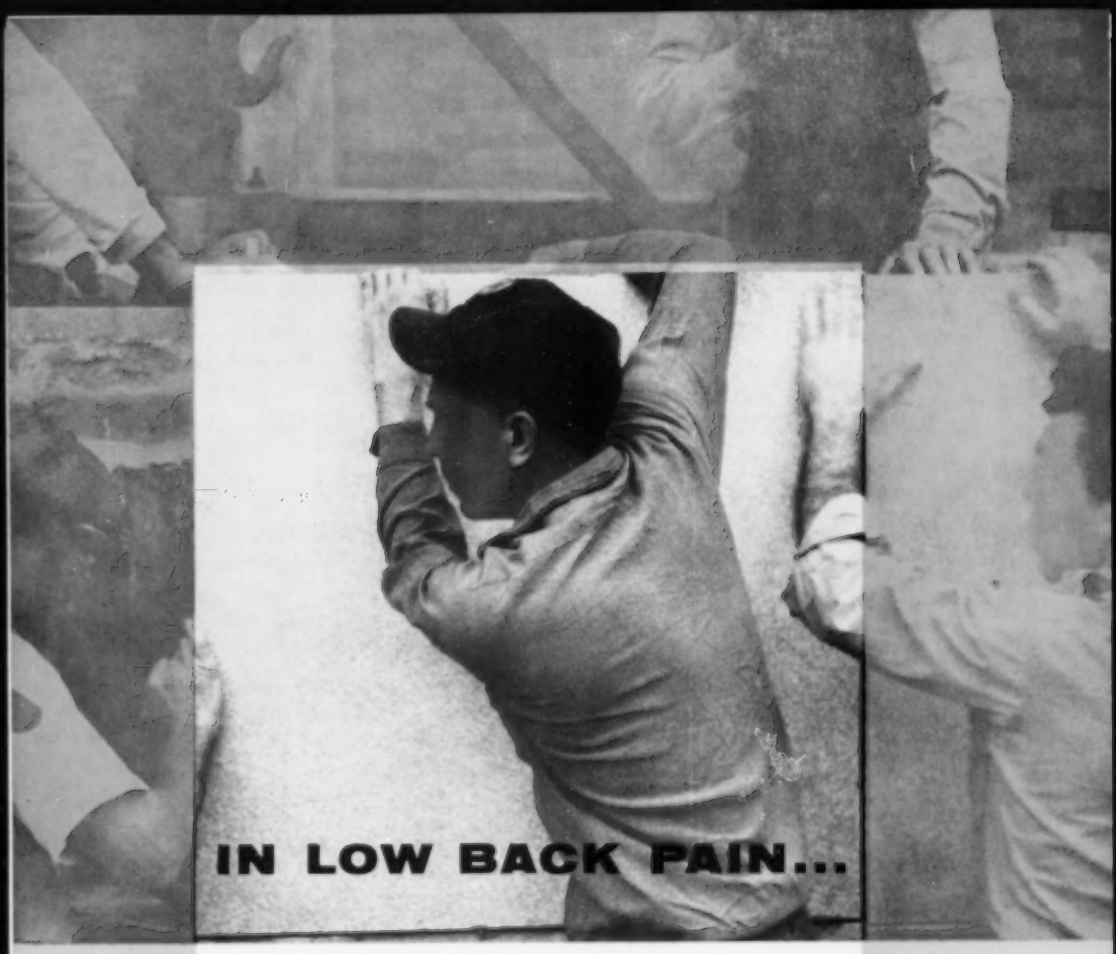

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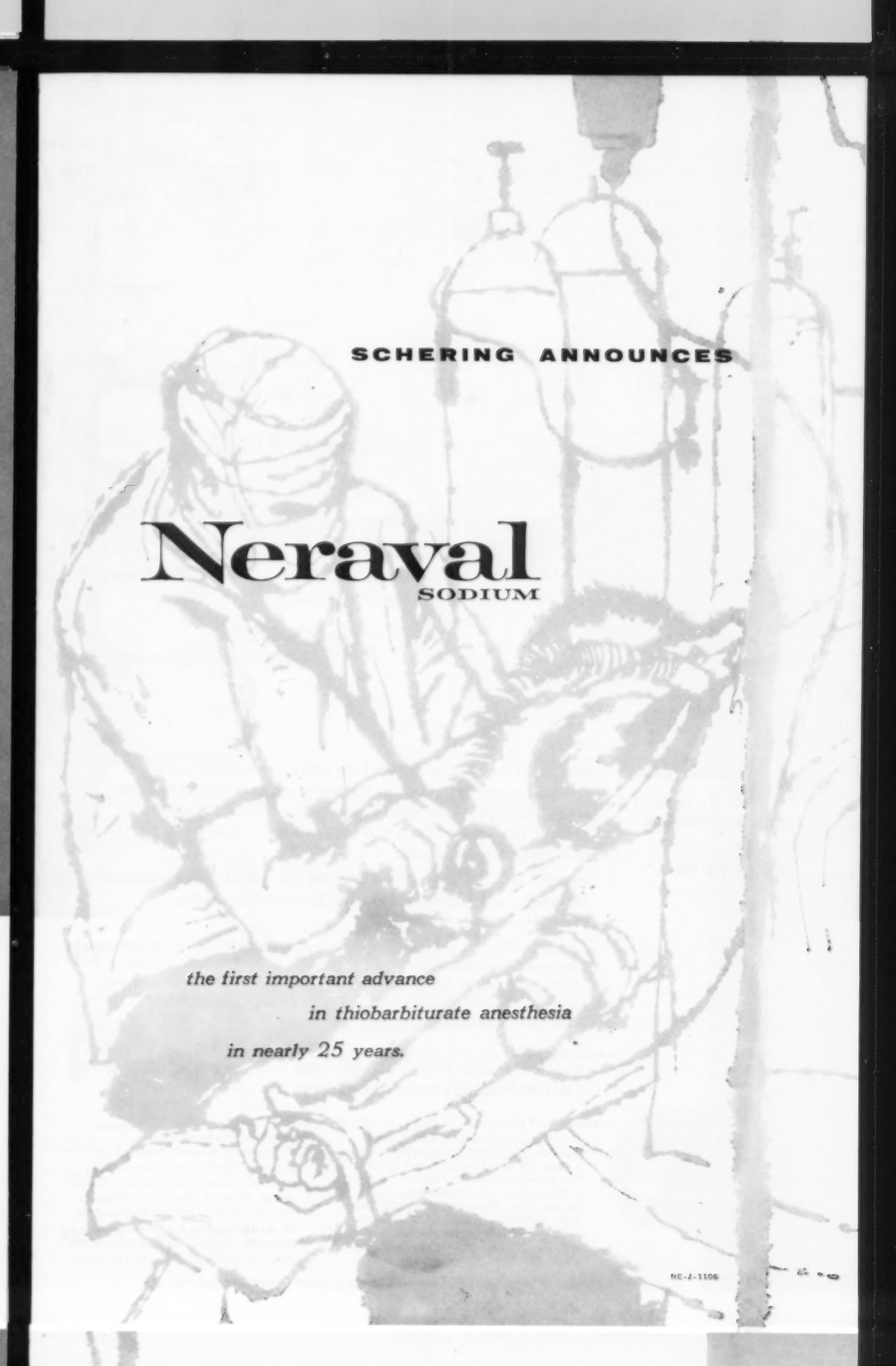
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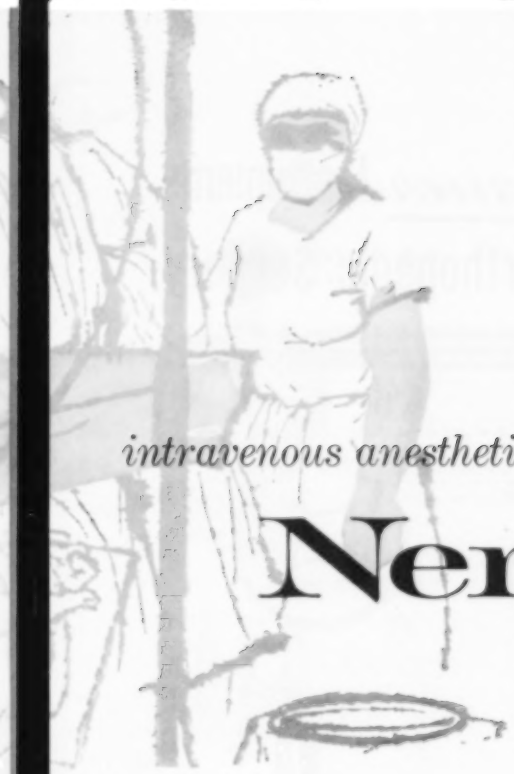

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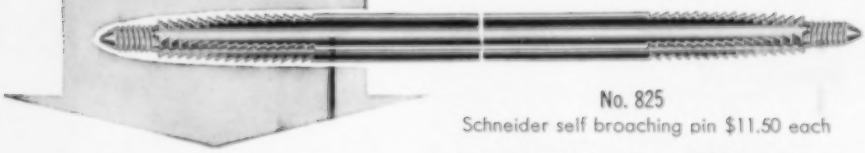

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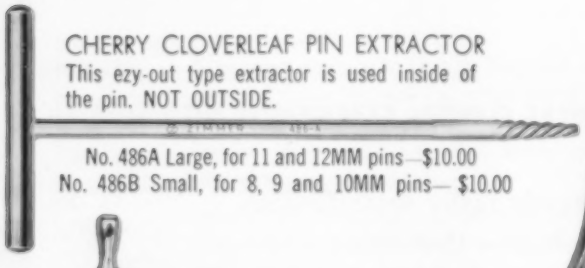

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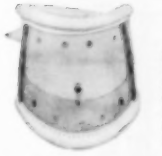

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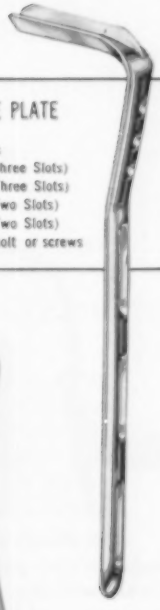

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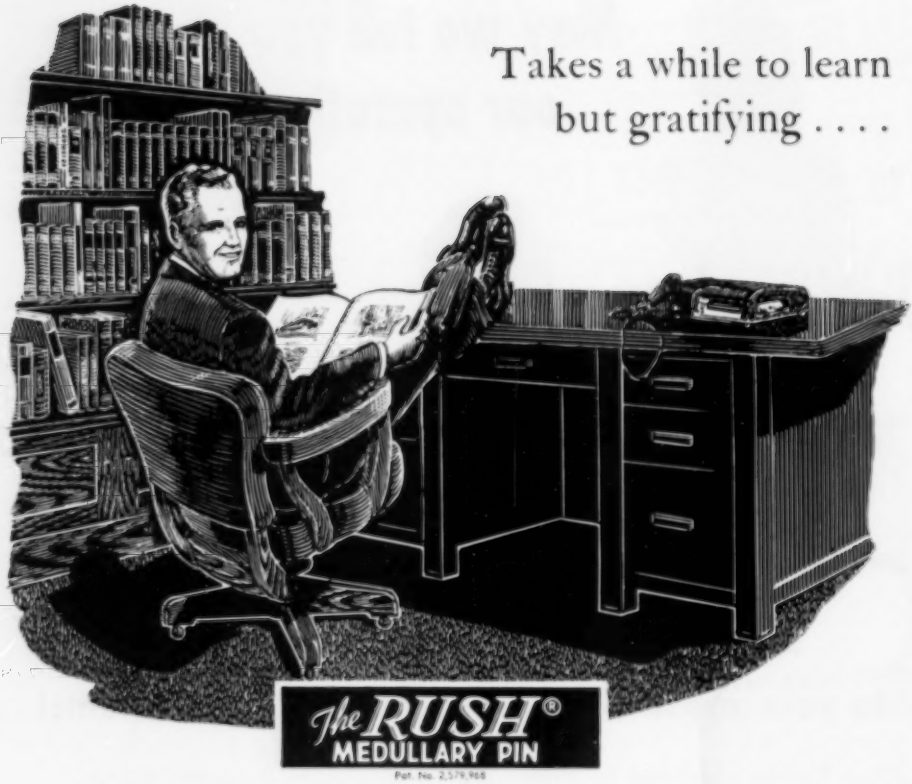

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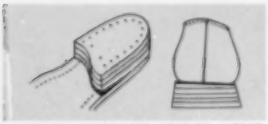
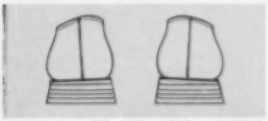


TRU-GUIDE BROAD-BASE LEATHER WEDGE HEELS BUILT FOR EASY ADJUSTMENTS



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• *and all Poll-Parrot Shoes are Pre-Tested*

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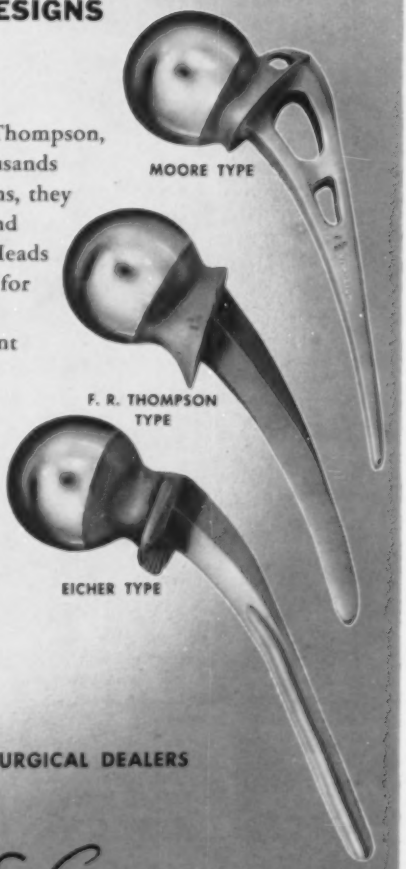

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1. *Prednisolone buffered*—the newest and most potent of the "predni-steroids" for prompt relief of joint pain and arrest of the destructive inflammatory process.

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	relieves pain	suppresses inflammation	relaxes muscle	eases anxiety	imparts sense of well-being
Salicylates	✓	✓			
Muscle relaxants			✓[1]		
Tranquilizers				✓[1]	
Steroids	✓	✓			✓
MEPROLONE	✓	✓	✓	✓	✓

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The pressure you apply is the pressure Tensor maintains... without constriction

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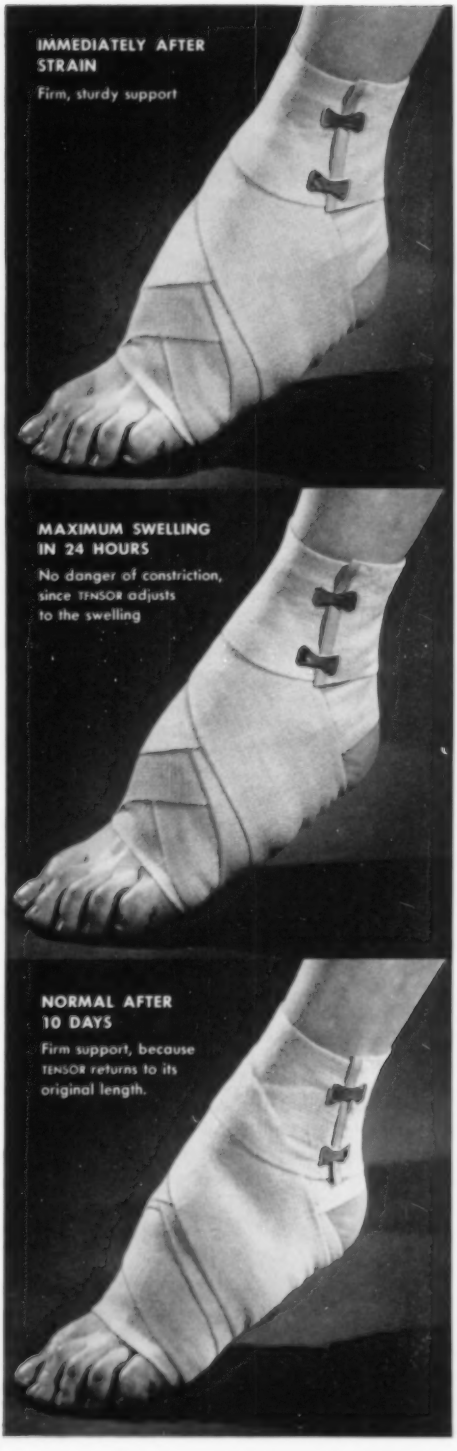
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MAXIMUM SWELLING IN 24 HOURS
No danger of constriction, since TENSOR adjusts to the swelling
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Firm support, because TENSOR returns to its original length.

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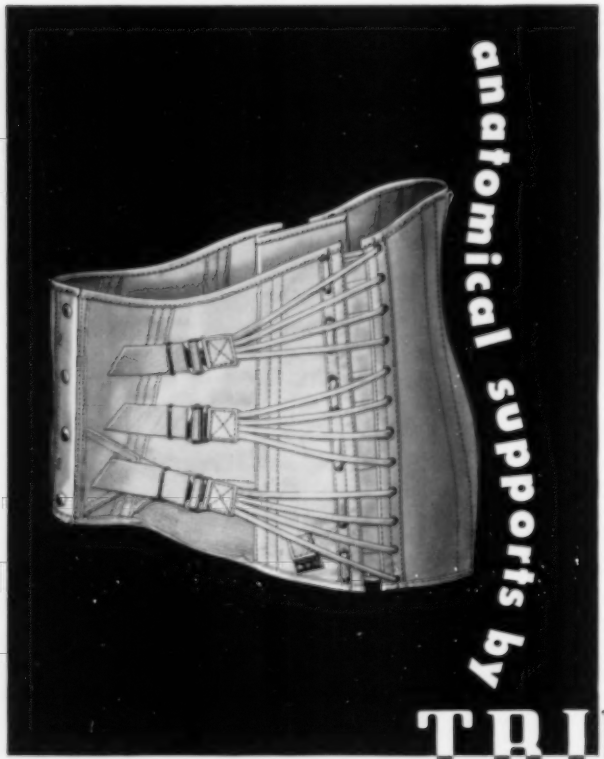

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Based on the most modern research program

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Alden-Pedic lasts and shoes have been scientifically designed and tested to accommodate specific and general degrees of foot disabilities. To fit the foot shape and accommodate the prescribed corrections is the crux of our program. Doctors who become familiar with the functional merit of this program will be glad to prescribe these shoes as a foundation in the treatment and correction of foot disabilities. We do not claim that these shoes will correct abnormal foot conditions, but they will provide the types of basic footwear necessary as a foundation in aiding foot trouble and in offering foot comfort. We know you will be glad to recommend them.

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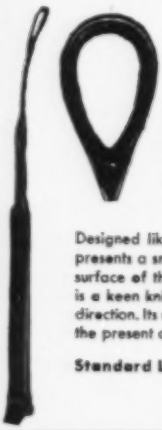

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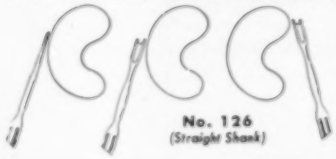

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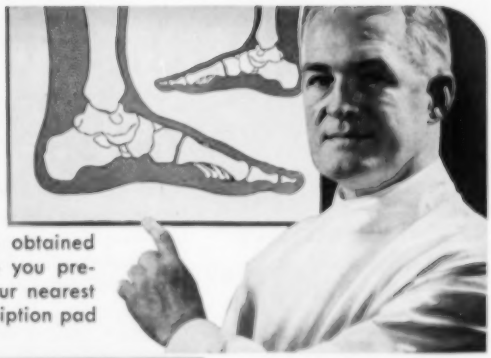

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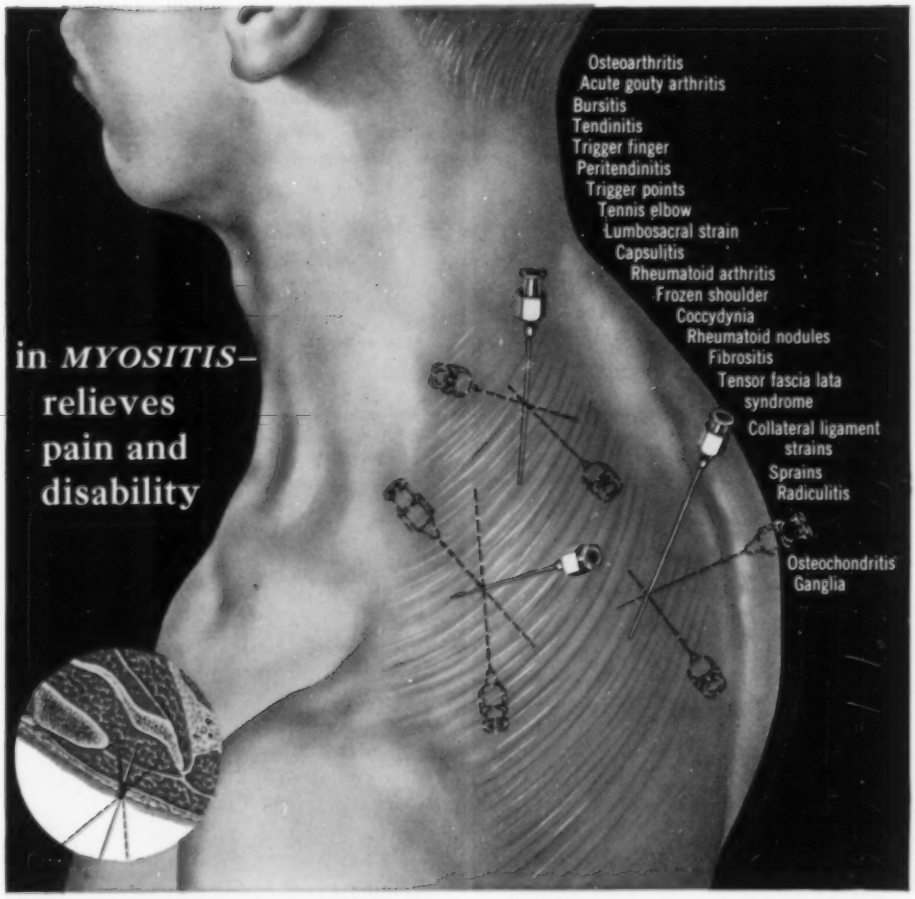
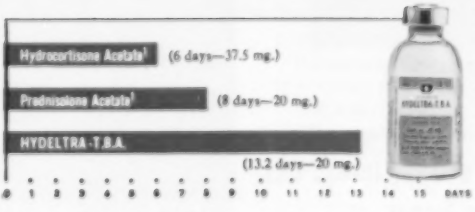
(Prednisolone *tertiary*-butylacetate, Merck)

for relief that lasts—longer



Anti-inflammatory effect lasts longer than that provided by any other steroid ester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HYDELTRA-T.B.A. (13.2 days—20 mg.)
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1. Hollander, J. L., *Paper read at conference in New York City, May 31 and June 1, 1955*

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Tibial Nail diameters: 5/16" and 3/8"

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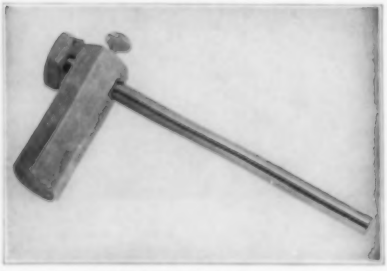

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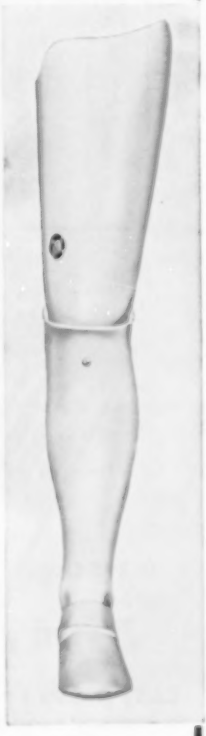

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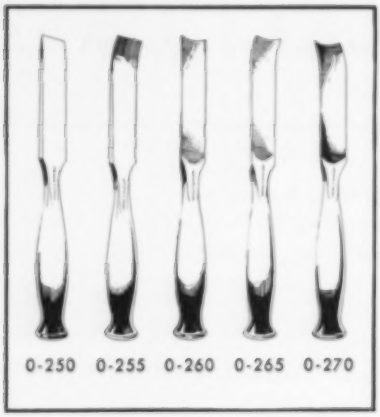

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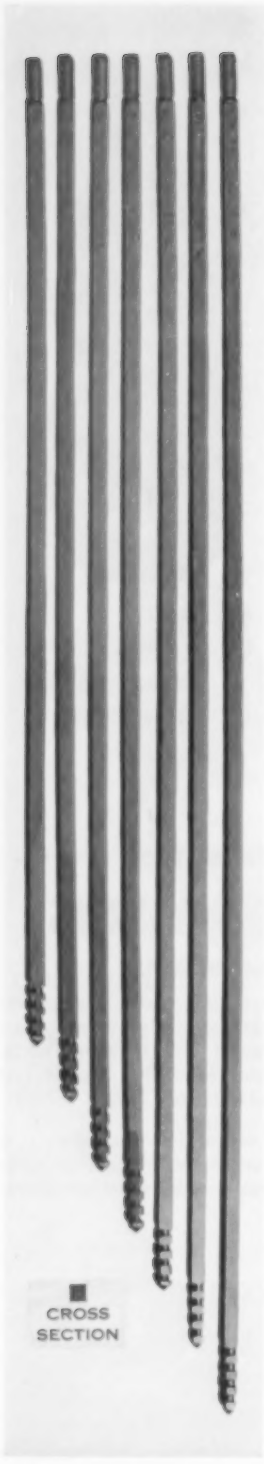

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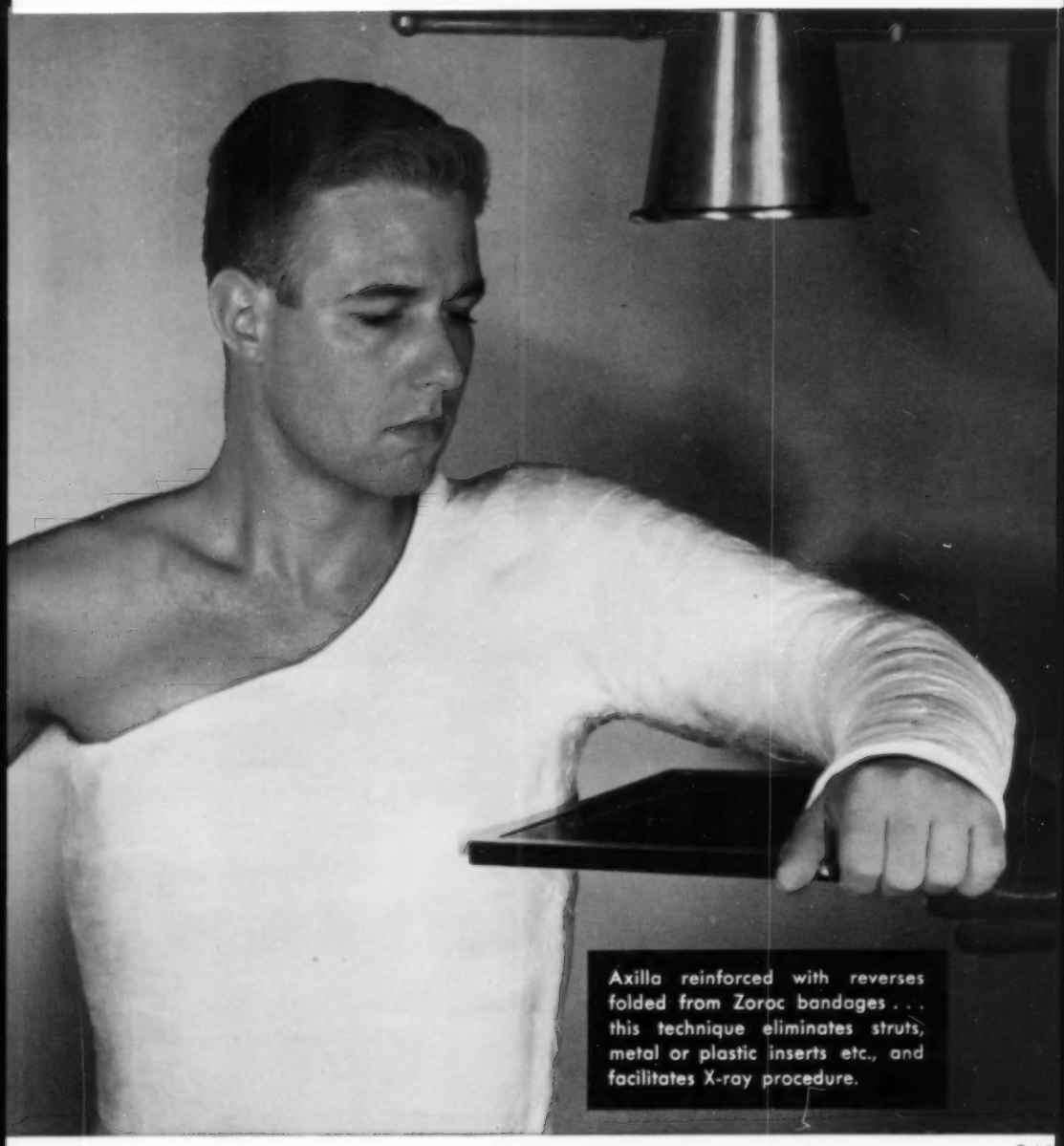

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The Journal of
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Constructive Hip Surgery With the Vitallium Mold

A Report on 1,000 Cases of Arthroplasty of the Hip over a Fifteen-Year Period*

BY OTTO E. AUFRANC, M.D., BOSTON, MASSACHUSETTS

From the Massachusetts General Hospital, Boston

INTRODUCTION

This report presents the results in and the lessons learned from a group of patients who had Vitallium-mold arthroplasties of the hip. Such a report may be biased because I believe in the principle of mold arthroplasty, because I have learned a great deal about how to use it, and because I have had a personal hand in the surgery and after-care of all of the patients. In order to overcome most of this prejudice, the examination of many of the patients and the evaluation of all the data have been carried out by an orthopaedic surgeon, Dr. Elliott Sweet, who had nothing to do with the surgery or the convalescent management of these patients.

The late Dr. M. N. Smith-Petersen, Dr. Carroll Larson, and I have either done or supervised the surgery in all of the patients.

MATERIAL

All of the patients were subjected to hip surgery at the Massachusetts General Hospital. The first Vitallium-mold arthroplasty of the hip was done in June 1938. The patient had bony ankylosis of his left hip and a rigid spine resulting from rheumatoid arthritis. In 1941, mold arthroplasty was done on the right hip. When he was last examined, the patient had no pain, walked with crutches, and worked at household chores. He could dress himself except for putting on his shoes and socks. He had 75 degrees of flexion in the left hip and 85 degrees in the right hip. There was no flexion deformity. He reported by letter, not long ago, that he had no pain, that he still used crutches, and that he was a little stiffer than he was when last examined. He could still dress himself, except for the putting on of his shoes. He was active from 8:00 in the morning to 9:00 at night with household chores and visits to neighbors. He occasionally took an afternoon rest. He was sixty-five years old.

Vitallium-mold arthoplasty is still being done at the Massachusetts General Hospital. It is almost eighteen years since this procedure was first applied to hip conditions. During these years over 1,000 patients have had arthroplasties; over 200 of these have had arthroplasties bilaterally.

* Read at the Annual Meeting of The American Orthopaedic Association, Banff, Alberta, Canada, June 23, 1956.

The present report is concerned with 1,000 consecutive patients (Table I). The patients operated on more recently are in an active convalescent stage. Except to say that I believe a greater range of motion, less pain, and more stable hips are being obtained now than previously, due to the use of a true-arc mold of slightly greater size than a hemisphere, the use of improved instruments and technique, and a better understanding of convalescent care, I am not concerned with these recent patients in this report.

An accurate follow-up study has been made of Massachusetts residents who had had Vitallium-mold arthroplasty of the hip during the years 1946 through 1954. This study, in which there was a 91 per cent follow-up examination of available patients, is to be reported at a later date.

TABLE I

MATERIAL

Total patients	1000
Both hips	193
Supplemental surgery	225
Sepsis	43
Died	3

EVALUATION

The evaluation terms *excellent*, *good*, *satisfactory*, and *unsatisfactory* are, in general, self-explanatory. An over-all evaluation of *satisfactory* indicates the patient's condition has been improved and that the surgery was worth doing. A surgical or clinical evaluation of *unsatisfactory* implies dissatisfaction or that the over-all condition of the patient has not been improved. Not infrequently, however, a rating of *unsatisfactory* by the surgeon becomes *good* or *excellent* in the patient's evaluation. This difference in rating, for example, is encountered in the bedridden patient with rheumatoid arthritis and bilateral bony ankylosis of the hips who has been mobilized by one or multiple procedures. He would favor having the surgery all over again simply to prevent himself from being completely disabled again.

The reverse of this is occasionally true. A surgical evaluation of *excellent* is not unusual in a mold arthroplasty done after a dislocation of the hip with an extensive fracture of the acetabulum. This evaluation may be slightly slanted by the surgeon because of what the result might have been if surgery had not been done. The patient's point of view is slanted in that he had a normal hip before the injury and anything less than normal is unsatisfactory to him. The right evaluation is probably somewhere in between as these and other emotional factors cannot be overlooked.

The analysis of the data in general confirms clinical experience. However, the figures, even in the data tables, may have no statistical significance. I do not attach any such significance to them; I use them, as the statistician probably does, to determine trends.

Fig. 1: B. L. Surgical view of a hip ten years after a Vitallium-mold arthroplasty. The patient had rheumatoid arthritis with a bony ankylosis of both hips and knees. It was necessary to do supplemental surgery because of overgrowth of bone and increasing limitation of motion.

Fig. 2: N. A. Seven and one-half years after a mold arthroplasty. This patient always had some pain after the original procedure; there was increasing pain and limitation of motion. Notice the white areas on the femoral head and in the acetabulum which are bare bone (Fig. 4). The finding of bare bone, more often on the head, has been frequent in those patients requiring supplementary surgery for persistent pain without physical findings or x-ray evidence of what might be the cause. After the supplemental surgery and removal of these areas of bare bone the patient reported that his preoperative pain was gone. This patient has remained free of pain and has maintained about a normal range of motion. She walks without support and without a limp.

Fig. 3: A. A. Five years after arthroplasty (Fig. 5). Supplementary surgery was done to increase the range of motion. The motion gained has been maintained and the patient denies pain.

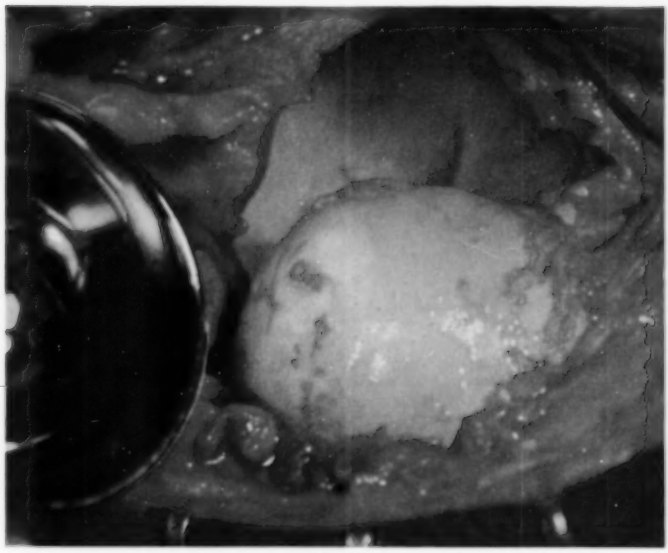

FIG. 1

FIG. 2

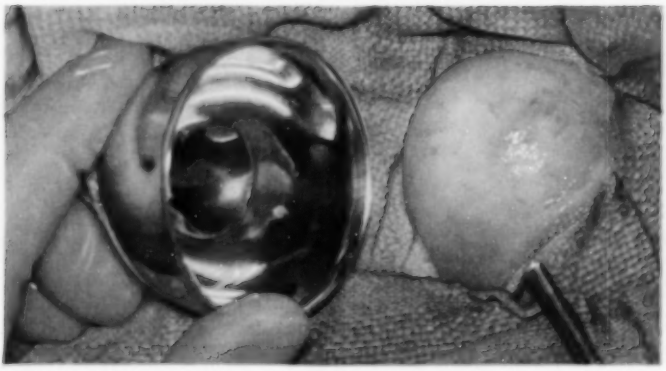

FIG. 3

Another feature which makes it impossible to evaluate the results in these patients accurately is the general impression of what the condition would have been if the surgery had not been done. In the final analysis, a procedure is worth while if the patients who have had it would be willing to go through it again for the same gain. Such a group of patients would normally include all of those with satisfactory results and better. Even in most of the unsatisfactory results the patient and the surgeon are in general agreement that the surgery was worth while, even though the anticipated result was not accomplished.

Any clinical research worker is struck almost immediately by the poverty of useful information in a clinical record. This poverty is so great for specific cases such as ours, that it is almost necessary to assume that the patient's condition was severe enough for

TABLE II

CLINICAL EVALUATION

PATIENT EVALUATION	Excellent	Good	Satisfactory	Unsatisfactory	Total
Enthusiastic	45 (100%)	115 (66%)	276 (46%)	29 (16%)	460 (46%)
Satisfied		55 (31%)	216 (36%)	83 (46%)	360 (36%)
Non-committial			66 (11%)	29 (16%)	100 (10%)
Dissatisfied		5 (3%)	36 (6%)	36 (20%)	80 (8%)
Total Patients	45 (100%)	175 (100%)	600 (100%)	180 (100%)	1,000 (100%)

one or several reasons to warrant the operation since he had had it. Any attempt to compare accurately his condition before the operation with that after the operation was actually impossible. The best that could be done was to question the patient as to his preoperative condition and to compare his answers with the fragments in the record. The information elicited often did not seem to correspond with the clinical record or apply to the patient. Even those records in which adequate preoperative information had been recorded by a reliable person would differ materially from the patient's memory of his preoperative condition. An enthusiastic patient would recall how severe his condition had been before surgery, while a patient with an unsatisfactory result remembered that he really was not so badly off before the operation.

In such evaluation, there is need for some simple terms to express the present condition of the patient and not necessarily the end result. Such functional factors as range of motion, strength, durability, self-sufficiency, independence, or limitations must all play some part in deciding whether or not the patient has an excellent, good, satisfactory or unsatisfactory result.

The time of evaluation after surgery also causes the recording of the result to vary. Contrary to some reports, we have found that it is usual for the patient to say he is better this year or this month than last year or last month. In some instances, patients who three years after surgery, were dissatisfied with the result obtained, were enthusiastic ten years after surgery. An occasional patient had used a cane for support for five years or more and then had discarded it entirely, maintaining good to excellent gait without discomfort. Others preferred to continue to use a single crutch for major walking (particularly right-handed people whose right hips were involved) although they were able to walk well without support. This is especially true of patients over seventy years of age.

The use of a walking support is generally looked upon by the public and many of our medical friends as the badge of failure. It is not. If we can make our aids adornments, they are accepted; they are not so acceptable, however, if there is the slightest hint of a limp or of a hitch in the gait or if there is a need to use a cane for better walking or for a

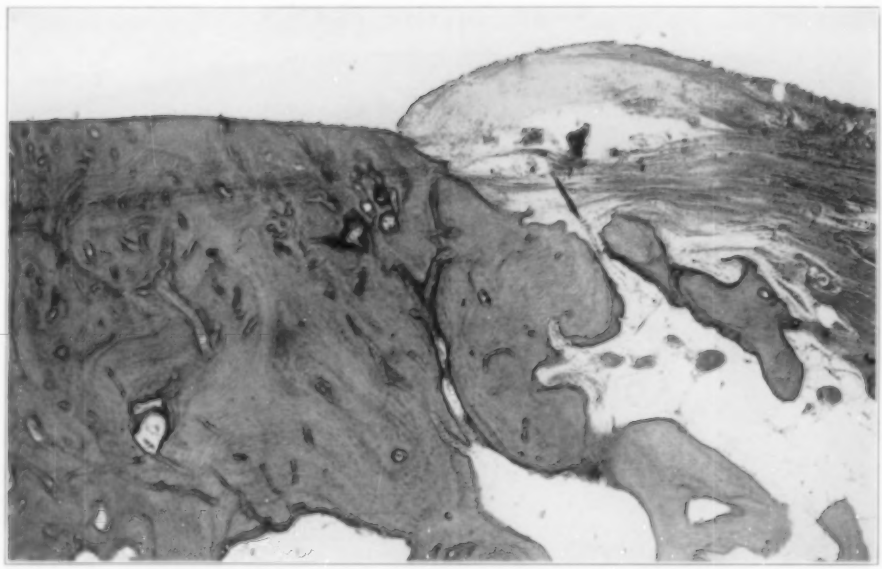

FIG. 4

High-power section through the margin of a "corn" on the femoral head where the healing has been interrupted (Fig. 2).

more active life. Those of us who deal with maintaining locomotion agree whole-heartedly with Dr. Blount that patients should not throw away the cane.

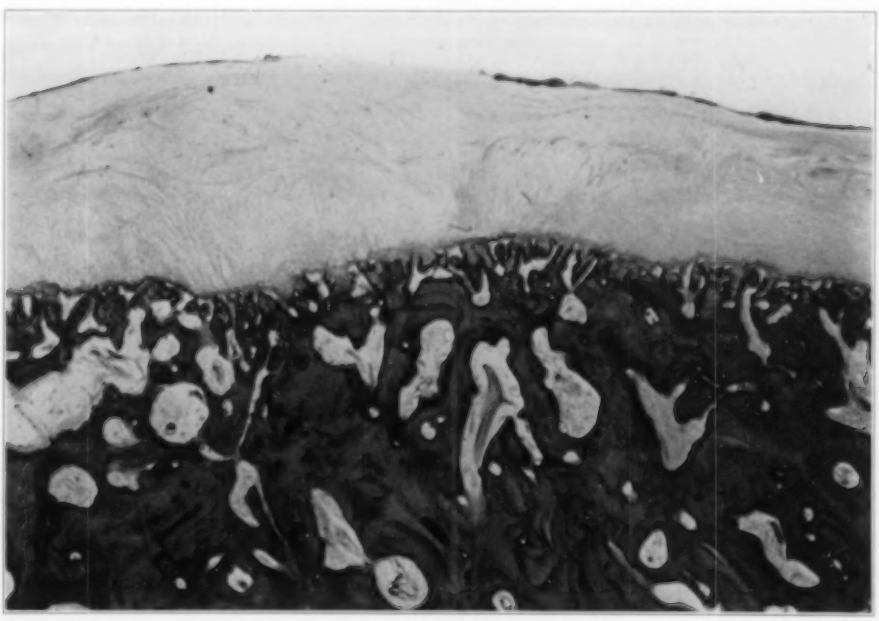

FIG. 5

Microscopic section through the fibrocartilage on the femoral head (Fig. 3). The fibrous strands seem to arise vertically from the bony base and then stream out horizontally as they near the weight-bearing surface. This general pattern was found in many other specimens.

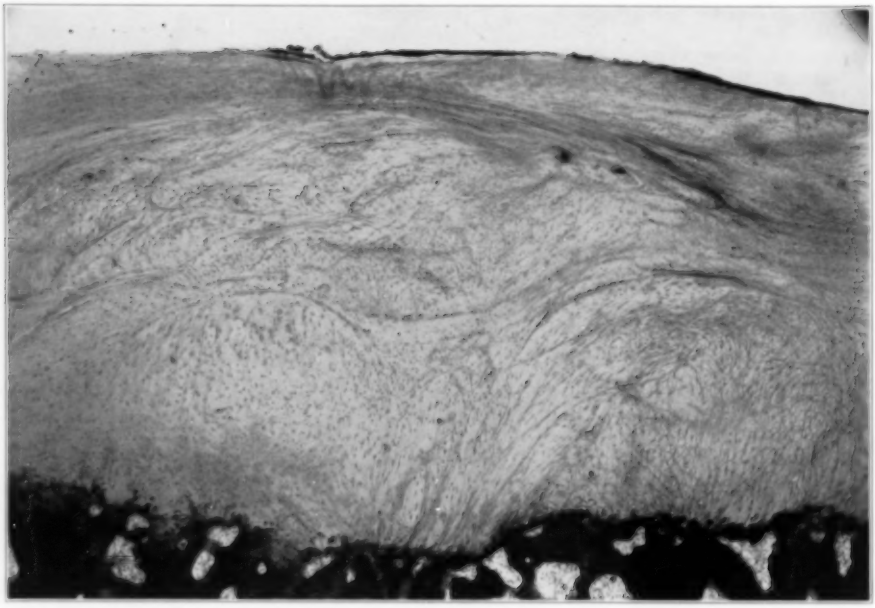

FIG. 6

G. M. Six years after arthroplasty. Section of a femoral head in a patient who had rheumatoid arthritis. This is fibrocartilage.

LESSONS

In the surgical evaluation, the excellent results have taught nothing, but they give hope and a goal. Often, it is not known what was done or what the patient did that

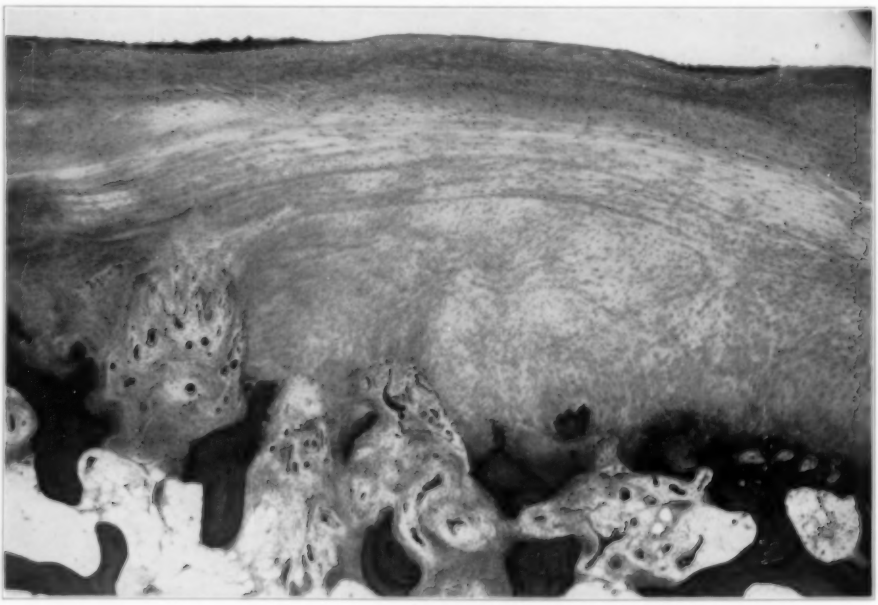

FIG. 7

A. C. This is a section of a femoral head showing fibrocartilage. (Areas were considered by an eminent pathologist as indicating the presence of hyaline cartilage.)

TABLE III

PAIN

	Per cent
Denies pain	22
Slight to none at rest	31
Moderate—at times	29
Uncomfortable—unpredictable (aware of hip most of the time)	17.2
Pain all the time	0.8

made the result so good. The roentgenograms may not show a good result and the patients may not have followed a good program. Often, however, the roentgenograms show good results and the patients have followed instructions carefully.

The good and satisfactory results keep one from being content with what has been done. The result might have been better if something had been done differently at surgery or if the after-care had been managed differently or if the patients had been better understood. It is through study of their cases and analysis of their problems and their personalities that technique has been improved and convalescent programs have been developed to suit the needs of the individual patient.

The unsatisfactory results have taught the most of all. Patience, understanding, and a genuine concern for the patients' welfare are most important. By listening to all of their complaints, by reviewing all of their activities, social as well as physical, and by carefully analyzing the subjective and objective findings through repeated examinations, a simple source of trouble may be found. It may then be easily eliminated. By working carefully, unhurriedly, and gently with these patients satisfactory, good, and, at times, excellent results have been obtained. But in those patients who continue to have pain, who lose motion and in whom deformities and poor gait develop, it becomes necessary to recommend further surgery.

In the early days further surgery was called revision. This implied that little, if anything, had been accomplished by the original procedure, while in fact much may have been accomplished in the relief of some pain, the correction of a deformity, or the development of muscle control. In those patients in whom there had been bony ankylosis, a fair range of motion may have been obtained. It is, thus, more accurate to call further surgery supplementary surgery and, at the same time, ease the conscience of the surgeon and soften the blow to the patient. Both are medical necessities. However, as long as the over-all condition of the patient continues to improve or does not deteriorate, supplemental surgery should be delayed.

TABLE IV

COMPLICATIONS

Deaths	3
Thrombophlebitis	50
Pulmonary emboli	37
Subluxations	16
Dislocations	4
Transient peroneal palsy	1
Permanent peroneal palsy	1
Fractured neck of femur	3
Fractured shaft	2
Jaundice (probably from blood)	2
Femoral nerve (motor) severed	1
Femoral nerve (motor) partially severed	1

TABLE V

SEPSIS

43 Patients (4.3 per cent)

	Patients
Rheumatoid arthritis (214 hips)	8
Old septic cases (80 patients)	13
Old fractures—septic before arthroplasty (121 patients)	7
Others (including ten tuberculous patients)	15
Cups removed	12

In revisions or supplemental surgery the prime lesson learned has been the healing of tissue. That knowledge must be applied to the management of these patients. Let us consider the facts of an arthoplasty of the hip. Raw bleeding bone (in fact the fractured ends of bone) is shaped and the attachments of muscles of great strength are released. A major joint is dislocated. All of this needs to heal. First, the fractured femur cannot be trusted to bear weight for many months to a year and full weight-bearing should not be allowed until enough time has passed for firm healing of tendon and bone. A program of gradually increasing activity and weight-bearing has been evolved which gives safe margins for these activities. Secondly, it would be folly to expect muscles that have been

TABLE VI

SUPPLEMENTAL SURGERY

225 Revisions (22.5 per cent)

	Per cent
Rheumatoid arthritis	36
Old septic cases	30
Congenital hips	22
Old fractures of neck (7 cases septic at operation)	14
Malum coxae	4
Fracture dislocations (2 cases)	0.8

weak for months or even years to become strong in weeks. The one great goal to be obtained in a hip patient is durability. Durability seems to result more certainly in those patients who follow the rules and who protect the hip until enough time has elapsed for firm healing to have taken place.

The general timing of protection in these hips has been arrived at by the application of the general knowledge of bone healing as long-term protection. Gentle, simple muscle-setting exercises and active, assisted motions in bed are begun and continued within the limits of pain-producing motions. Any exercise or motion that produces pain which lasts any length of time afterward is made less strenuous. If by reducing the effort by one

TABLE VII

DURABILITY

(A changing quality)

	One Hip (Per cent)	Two Hips (Per cent)
Support all of the time (cane or crutches)	27	55
Support part of the time (cane or crutch)	40	30
No support	33	15
Walk up to one mile	50	47

half, the exercise or motion still produces pain that lasts, then that specific activity is discontinued for several days or until all of the pain is gone. It is then resumed at a slower pace or an easier motion is substituted that will often accomplish the same thing.

The motion and friction of partial, comfortable weight-bearing are the elements that make for a durable joint. Weight-bearing must be actively protected until the full range of motion has been obtained. If early full weight-bearing is allowed (under six months), it is possible that the patient may wear through the healing on the head of the femur and in the acetabulum (Figs. 2 and 4). There have been a number of patients who have been very comfortable until some specific episode produced pain on weight-bearing. From this they never recovered. Sitting too long, standing improperly, or frequently abusing the hip in other ways, such as trying to catch up on exercises, will produce this result. At supplemental surgery this wearing through the healing is readily seen. Belief in its pain-producing potential stems from the patients themselves. Often on recovery from these second operations they will say, "My hip is sore but *that* pain is gone."

Another lesson learned has been the need to transplant the iliopsoas tendon to the anterior medial border of the distal portion of the capsule in order to give the tendon a direct pull for function. This came about by finding the tendon embedded in the scar tissue between the mold and the acetabulum. Through having the muscle pull directed across the front of the mold, the muscle functions more efficiently, stabilizes the joint, diminishes the tendency to a permanent flexion deformity, and prevents a position of external rotation. In patients with a short femoral neck or in those with no neck, as in a shaft arthroplasty, it is necessary to move the greater trochanter with its attached abductors down the lateral portion of the shaft, or to insert the tendons of the abductors into the vastus externus[10].

The other lessons learned are totally unsupported by statistical evidence of their worth; I list them on simple faith:

1. The reconstruction of the hip is not complete until the hip is relatively stable through its major functional positions.

2. The head of the femur and its acetabulum both need to be reconstructed and reshaped until they fit comfortably together with the interposed mold without strain.

3. The muscles that are to move the hip should have functional force lines toward stabilizing and moving it efficiently.

4. In the surgical closure of such a hip, the tissues should fall together without undue tension.

5. A full range of motion should be obtained before full strength is tried for, for this will prevent excess new-bone formation.

6. A long period of walking with crutches with a *comfortable* amount of partial weight-bearing as a major part of the exercise program is recommended; this should be continued (sometimes for as long as two and three years after the operation) until a strong hip has been developed.

7. In any patient who has a tendency to limp, adequate support in order to prevent limping is necessary. This may mean that a cane, a crutch, or crutches are needed to support the muscles part of the time until they are strong.

COMPLICATIONS

In any large series in which such extensive surgery as a reconstruction of the hip has been done, one would normally expect a death on the operating table. This has not yet happened. One patient died one week after surgery without regaining a conscious state. A most thorough postmortem examination failed to reveal the cause of death. The patient had said before going under the anaesthesia that she did not believe she would wake up. A second patient died three weeks after surgery of a cerebral vascular accident while on anticoagulent therapy for a presumptive diagnosis of thrombophlebitis. She had

stated that she was too old to go on with the pain in her hip and it was not really worth while to fix it as she did not have long to live anyway. A third death occurred four months after surgery as a complication of sepsis.

If I thought statistics meaningful, I would say that these three deaths might have occurred normally during this time in a sample of this size. None would doubt it, since the ages of the entire group ranged from eight to eighty years. I prefer to believe that our number of deaths were low because of the care in the preoperative evaluation, the preparation, during surgery, and, afterward, in convalescence. Most important was the excellence of the anaesthetists and the replacement of blood as it was lost. Blood replacement averages one unit of blood for every hour of operating time. The amount is greater in hips with old scars and sepsis.

Wound sepsis is a major disaster in the reconstructed hip. Hospitalization because of sepsis may extend up to two years and requires many operative procedures and countless hours of nursing care and results in untold misery to the patient and his surgeon. Everything possible is done to prevent this complication. Important precautionary measures, in addition to the standard antisepsis precautions, are: surgical preparation in the operating room; careful skin towel isolation, the use of local antibiotics at the time of closure of the wound, *a thorough débridement of all tissue strands, traumatized capsule, and muscle before closure*, and a surgical closure of the tissues without undue tension.

Thrombophlebitis has not been a common complication. Often the swelling of the extremities and muscle soreness in an exercise-enthusiastic patient may be mistaken for thrombophlebitis.

Absorption of the head and shortening of the neck under the mold have occurred. These have not been as much of a problem as had been anticipated; it was difficult to discover ten patients with these complications. Those in whom they occurred include two patients with sepsis, one patient with rheumatoid arthritis, one patient with intrapelvic protrusion, one patient with degenerative arthritis, one patient with an old fractured neck of the femur with aseptic necrosis, three patients with Charcot hips, and one patient with tuberculosis. In all of these absorption and shortening were proved during supplemental surgery. Undoubtedly there are other patients with more or less absorption in whom the complication was not sufficient to require supplemental surgery.

There is less absorption of head and less gradual intrapelvic protrusion of the mold if weight-bearing is protected until bone healing has taken place and if weight-bearing is distributed over a larger surface. Thus, as large a mold as is practical is used.

Dislocations of the mold have been few, twenty, and are now a rarity since care is taken to shape an acetabulum with its dome properly placed and since muscles are transplanted whenever necessary in order to stabilize their functional forces.

MODIFICATIONS OF TECHNIQUE

Practically all of the arthroplasties in this report were done through the anterior approach. The general technique of exposing the hip as described by Smith-Petersen was followed. As a surgical procedure is repeated many times, it undergoes a normal evolution. Changes creep in unnoticed at first and then become routine. Other changes are very deliberately made as a result of need and experience. Some of these changes in technique have been described in the *Instructional Course Lectures of The American Academy of Orthopaedic Surgeons*, Vol. 9, 1954, and in the Third Edition of *Campbell's Operative Orthopedics*, 1956. Only a few of the principles involved need to be emphasized here.

Exposure of the joint should be comfortably adequate. Strong retraction of the tissues and skin that produce unnecessary trauma and ischaemia of long duration should be avoided. Sharp dissection, release of muscle attachments from bone, and slightly more than adequate subperiosteal reflection are preferable to overstretching and possible tearing of muscle.

Specifically, the following steps have been added at the proper sequence in the exposure. The skin and subcutaneous fat and fascia are isolated from the depth of the wound. This is done by suturing a saline moist gauze handkerchief to the deeper layers. This protects the superficial layers from drying and from the repeated and unavoidable trauma involved in the making of the new joint. The glutaeus minimus tendon is almost routinely tenotomized at the greater trochanter in order to allow exposure of the superior part of the femoral neck without undue reflection of muscle from the lateral wing of the ilium. The capsule, synovial membrane, and the straight and reflected heads of the rectus femoris muscle are reflected from the front of the joint in one piece. As nearly as possible, the capsule and synovial membrane are left in place and serve as a protection to the surrounding structures from the normal trauma of bone work in reshaping the joint. Finally, after a thorough irrigation of the wound, the entire synovial membrane and capsule are excised. This results in a removal of all traumatized tissue and leaves freshly cut surfaces for healing in the depth of the wound. All devitalized strands of tissue are excised.

At times the exposure is made easier by tenotomizing the iliopsoas tendon as well as the glutaeus minimus. This is specifically true in patients with a shallow acetabulum or congenital dislocation of the hip. In these conditions, it is necessary to deepen the acetabulum medially and to secure the function of the hip in a more medial position. By transplanting the tendon of the iliopsoas to the anterior distal portion of the capsule, the hip is stabilized in this new position. The muscle has a straighter pull for function in flexion in this position.

Surgical closure of a wound about a joint requires approximation without undue necrotizing tension. After closure of the wound and after the sutures have been tied, the joint should be moved through its full range of motion. If the sutures have been properly placed, they will not break or pull out.

After-care of these patients has been adequately covered previously[2, 3]. The general principles of this care seem worthy of emphasis. Protection should be maintained until bone healing is sufficient to allow weight-bearing on a mechanically levered joint. Since this leverage is more than the body weight, protection should extend in time until dense bone healing has taken place. This will require many months, sometimes a year or more.

Motion is secured by gentle persuasion and by support of the joint and the muscles. This support should last as long as there is any tendency to soreness or to limping, with an immediate return to crutches or cane support should there be any recurrence of soreness or limping. This should continue for a safe margin beyond the time of the disappearance of the soreness and limp. The strength of the muscles may be safely developed after an adequate range of motion has been obtained but not before firm bone healing has taken place.

SELECTION OF CASES

Mold arthroplasty is a procedure of choice in cases of bony ankylosis, traumatic or degenerative arthritis, old and fresh fractures of the acetabulum, rheumatoid arthritis before and after ankylosis (preferably before), old septic hips with and without draining sinuses, and as salvage following failure of other procedures including the insertion of a prosthesis and previous mold arthroplasties. In the salvage procedure, a shaft arthroplasty is done with the mold placed on the end of the femur. In this, the abductors must be transplanted down and the iliopsoas must be transplanted forward.

In patients with an adequate stock, the procedure has stood the test of eighteen years of experience with results which encourage its continued use. Congenital subluxations are particularly suitable for mold arthroplasty. In patients with congenital dislocation of the hip in whom there is an adequate femoral head and in whom an adequate socket can be developed, the results from the use of the procedure have been good and excellent. When there has been loss of a large area of the femoral head or when there is

inadequate material for arthroplasty, the femoral-head prosthesis can be used with encouraging early results.

Mold arthroplasty is a sound surgical procedure; it needs, however, to be properly applied. Good to excellent results will be more frequent if the patients are managed according to the principles of bone healing and of muscle control. In summary, I would like to say that if good to excellent surgery has been performed, these hips can be persuaded but not forced to a good or excellent result.

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(*Continued on page 316*)

Fracture of the Distal Radial Shaft

Mistakes in Management*

BY JACK C. HUGHSTON, M.D.†, COLUMBUS, GEORGIA

The high incidence of non-union, delayed union, and malunion in closed fractures of the radial shaft at the junction of the middle and distal thirds without an associated fracture of the ulna has not been appreciated. The usual cause of this uncommon fracture is a direct blow to the dorsoradial aspect of the forearm. Therapy does not appear to be difficult.

The cases represented in this report were selected and the study was made by members of the Piedmont Orthopaedic Society. This is our initial group study and we feel that the results are interesting enough to warrant presentation. The fracture appears infrequently and most of us are unfamiliar with it.

The characteristics of most fractures are well known and their response to various forms of treatment can be anticipated. It was once thought that this was true also of the fracture of the distal radial shaft.

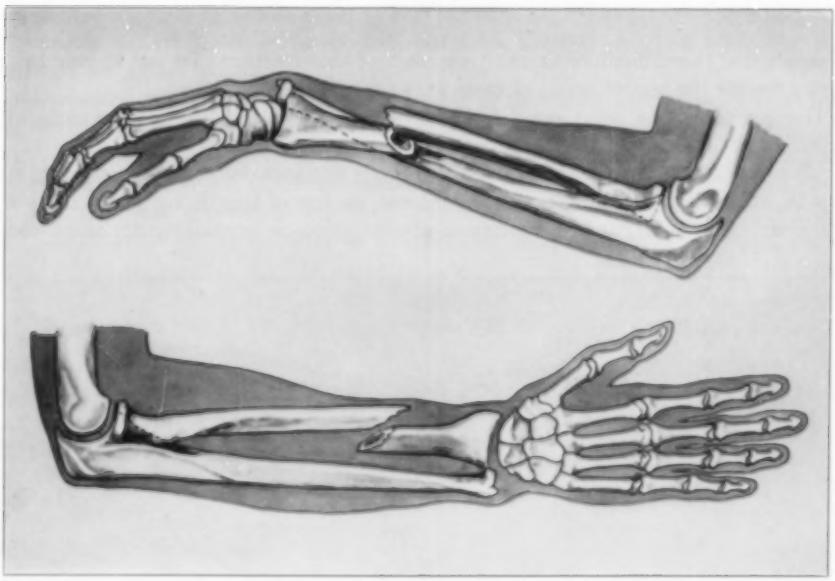

Fig. 1

A survey of the American and British literature revealed that the most recent article on this specific subject was published in 1922 [5]. A review of the French and German literature revealed recent articles which reported small series of cases [2, 3, 4, 6]. The French often call this fracture "a reverse Monteggia fracture". Our fracture textbooks [1, 7] do

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 30, 1956.

† Representing the Piedmont Orthopaedic Society which is composed of members of the Duke University Orthopaedic Training Program, Durham, North Carolina. It was formed for the purpose of investigating clinical orthopaedic problems.

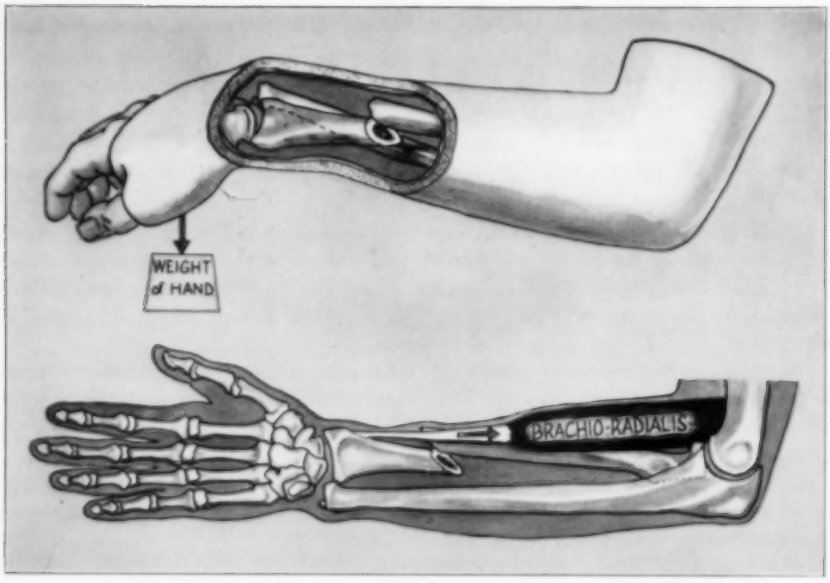

FIG. 2

not emphasize the difficulties in the treatment of this fracture. To our knowledge, this report presents the largest series of cases ever presented.

Our purpose is to point out mistakes frequently made in the management of the fracture of the radius and to offer suggestions for treatment.

The results have been classified as *satisfactory* or *unsatisfactory*. A satisfactory result is one in which there is union, perfect alignment, no loss of length, no subluxation of the distal radio-ulnar joint, and no limitation of supination or pronation. An unsatisfactory

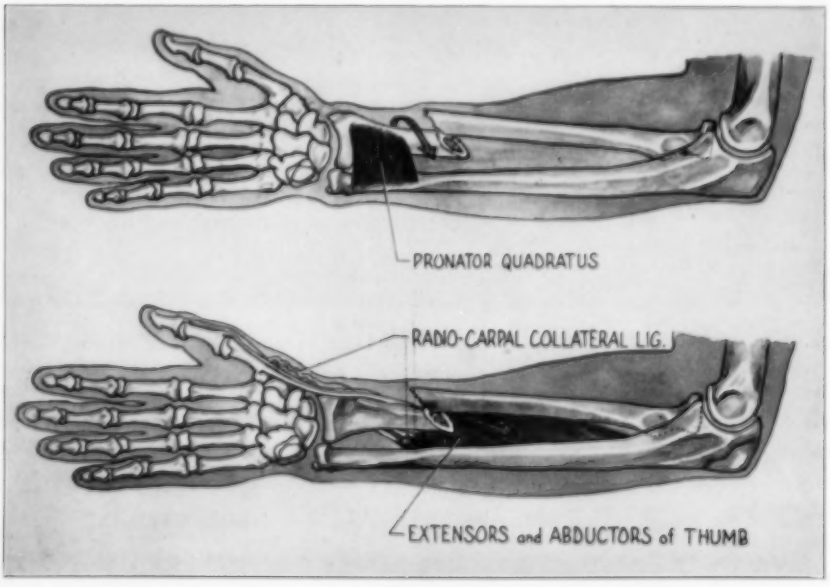

FIG. 3

TABLE I

TWENTY-ONE CASES IN EARLY-TREATMENT GROUP

Type of Fixation	No.	Satisfactory	Unsatisfactory
Round intramedullary pins	4	1	1 non-union 1 delayed union; ulnar subluxation 1 unknown results
Küntschner intramedullary pin	2	2	
Kirschner intramedullary pin	1	1	
Screw fixation	2	1	1 angulation and ulnar subluxation
Four-hole plates and screws	6	5	1 angulation and ulnar subluxation
Double onlay bone graft, four screws	4	3	1 non-union
Transfixation pins	1		1 angulation and ulnar subluxation
No fixation	1	1	
Total	21	14	6 Unknown, 1

result is one in which there is one or more of the following: non-union, shortening, angulation, subluxation of the distal radio-ulnar joint, or dislocation of the distal radio-ulnar joint, and some degree of limitation of supination. Our criteria of satisfactory or unsatisfactory results may be considered severe, but it is necessary to establish a rigorous standard of judgment. However, some of our patients and their physicians were pleased with eventual end results even though full anatomical re-alignment and functional restoration were not achieved.

We consider four factors as the major causes of deformity after reduction. Figure 1 shows the fracture and the usual resulting deformity. The weight of the hand, even while the arm, wrist, and hand are immobilized in a cast (Fig. 2), acts as a strong volar displacing force or pull on the distal radial fragment, resulting in subluxation of the distal radio-ulnar joint and malalignment at the fracture site. The fracture of the distal radial shaft occurs just proximal to the insertion of the pronator quadratus into the volar surface of the body of the radius (Fig. 3). The strong action of this muscle is frequently overlooked, and its role in the management of this fracture must be considered. The distal radial fragment is rotated toward the ulna and is pulled in a volar and proximal direction by

TABLE II

Elapsed Time After Fracture	Procedure	Satisfactory	Unsatisfactory
3 months	Double onlay bone graft		1 non-union
4 months	Double onlay bone graft		1 non-union
4 months	Double onlay bone graft		1 healed with ulnar subluxation
4 months	Kirschner intramedullary pins and bone graft	1	
5 months	Double onlay bone graft	1	
6 months	Resection of distal end of ulna	1	
6 months	Kirschner intramedullary pins and bone graft		1 delayed union and ulnar subluxation
11 months	Onlay bone graft, step-cut ulnar shortening		1 healed with ulna subluxation
1 year	Kirschner intramedullary wires, bone graft, distal ulnar resection		1 improved, but with functional limitation (50 per cent supination)
Total		3	6

FIG. 4-A

the pronator quadratus. The brachioradialis, inserting into the radial styloid process, utilizes the ligaments at the distal radio-ulnar joint as a pivot upon which to rotate. At the same time, it shortens the distal radial fragment on the ulna. The customary position of the hand for immobilization of the fracture can be considered ulnar deviation. The thumb, in line with the radial shaft, utilizes the radial collateral ligament for traction on the distal portion of the radius. The force of the thumb abductors and extensors, although not great, is enough to shorten the radial side of the wrist and thus to lead to relaxation of the radial collateral ligament.

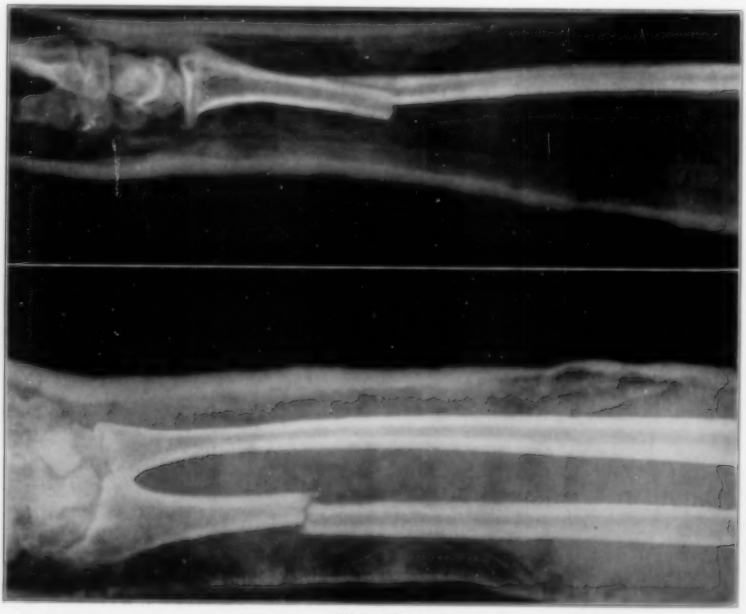

FIG. 4-B

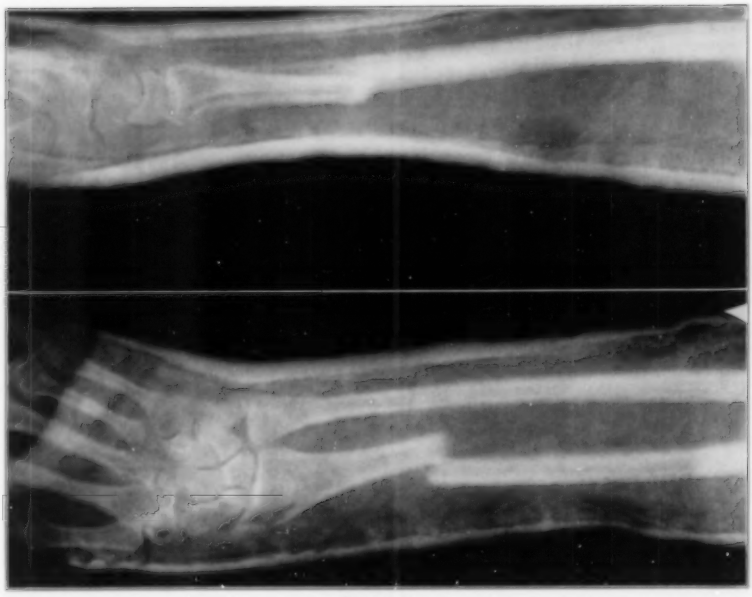

FIG. 4-C

The members of the Piedmont Orthopaedic Society assembled for study forty-one suitable cases of fracture of the radial shaft at the junction of the middle and distal thirds without an associated fracture of the ulna. The initial treatment in thirty-eight cases consisted in closed reduction and immobilization. In the three remaining cases, the initial treatment was open reduction and internal fixation. One of these fractures was fixed with a Kirschner wire, with satisfactory results. The second fracture, fixed with

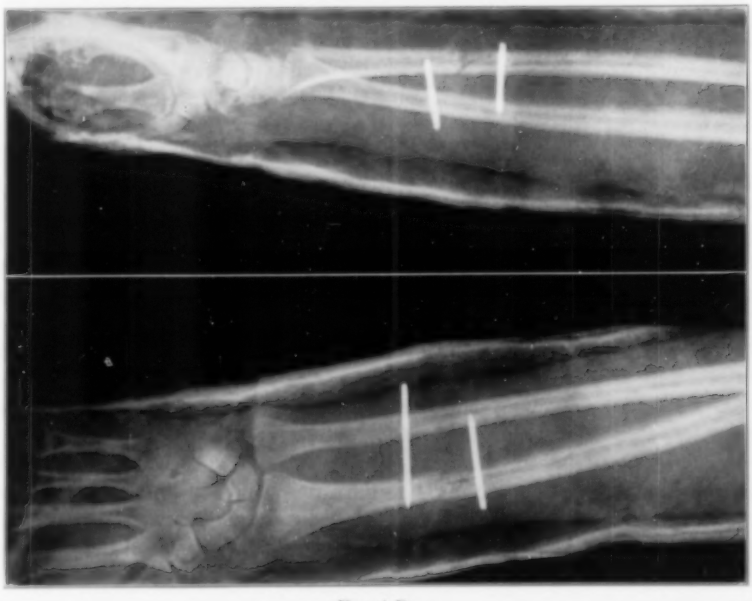

FIG. 4-D

a four-hole plate and screws and with an autogenous cancellous-bone graft, demonstrated delayed union; six months later the results were satisfactory. The third fracture was treated with a transfixation screw placed obliquely. The result of this fixation was unsatisfactory, for the screw loosened in the distal fragment and caused subluxation of the distal radio-ulnar joint secondary to the shortening and angulation of the radius.

Of the thirty-eight fractures treated conservatively, thirty-five (92 per cent) resulted in failure, and the results in the remaining three (8 per cent) were satisfactory according to our standards.

Twenty-four of the forty-one patients reported in this study received their initial treatment from orthopaedic surgeons. We were able to determine that, in twenty-one of

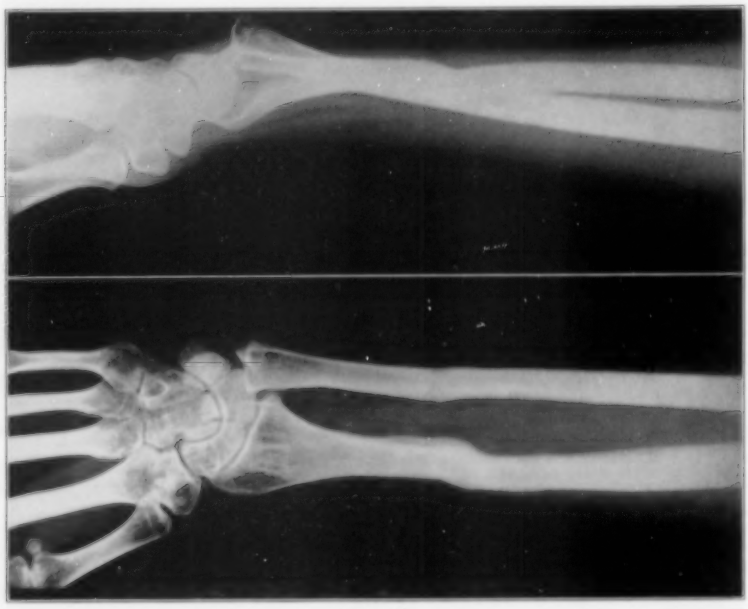

FIG. 4-E

these patients, this consisted in closed reduction and plaster immobilization of the arm with the hand in neutral position or in moderate or full pronation. We do not know the specific form of conservative treatment given the other twenty patients.

We believe that the high percentage of unsatisfactory end results in the treatment of this fracture is due to most physicians' lack of knowledge of the forces active when the customary reduction and immobilization is applied in the treatment of these fractures. The rareness of this fracture and, therefore, our unfamiliarity with it, accounts for our lack of knowledge of its complex aspects.

Of the thirty-five patients in whom results were classified as failures, seven refused further treatment. Twenty-eight patients submitted to open reduction or reconstruction. Twenty-one of these patients were operated upon within four weeks after fracture and were considered early-treatment cases. Seven patients were operated upon more than four weeks after their injury and were considered late-treatment cases.

Of the twenty-one fractures operated upon early (Table I), four were fixed with round intramedullary pins; in two of these the results were unsatisfactory. In one there was non-union, and in the other there was delayed union and subluxation of the ulna.

Two fractures were fixed with intramedullary Küntschner pins with satisfactory results. One fracture was fixed with multiple intramedullary Kirschner wires and the result was satisfactory.

Two patients had the fractures treated with screw fixation; in one, angulation and subluxation of the ulna occurred.

Six fractures were treated with four-hole plates and screws, with an unsatisfactory result in one because of dorsal angulation and subluxation of the ulna.

Four fractures were treated by double onlay bone-grafting; non-union resulted in one of these.

One fracture was fixed with transfixation pins to the ulna; the result was unsatisfactory because of dorsal angulation at the fracture site and dislocation of the distal radio-ulnar joint.

One open reduction without internal fixation resulted satisfactorily; in this case the

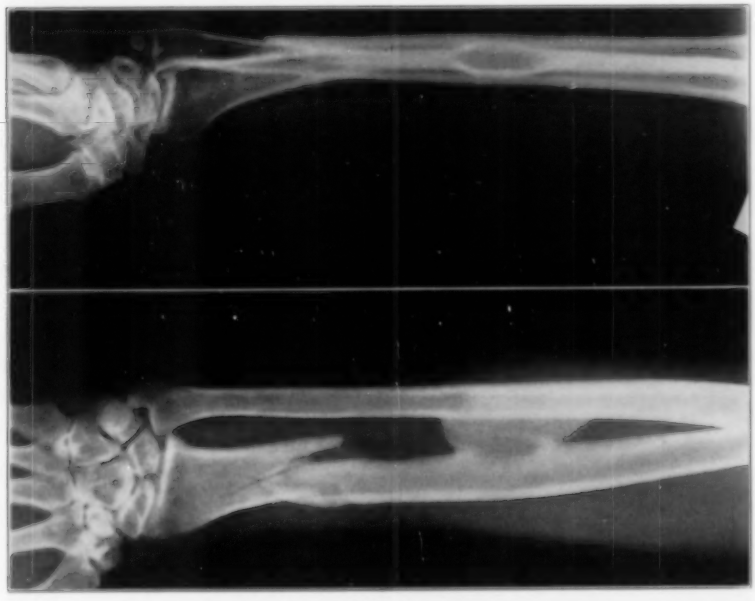

FIG. 5

oblique surface of the proximal fragment inclined toward the radius, and when anatomical reduction was obtained with successful matching of the interdigitations, the resulting radial obliquity forestalled the usual action of the deforming forces.

Of the twenty-one fractures operated upon early, the results in fourteen (67 per cent) were satisfactory, six (28 per cent) were unsatisfactory, and the results in one case (5 per cent) are unknown.

Later operative procedures were carried out in seven patients of the twenty-eight in the late-treatment group, as well as in two patients of the early-treatment group, in order to correct unsatisfactory results following the initial operative treatment (Table II).

In the nine fractures operated on late, there were unsatisfactory results in six (67 per cent) and satisfactory results in three (33 per cent). In the late-treatment group of twenty-eight patients there were eleven (40 per cent) with unsatisfactory results and seventeen (60 per cent) with satisfactory results.

Of these twenty-eight fractures treated by open reduction and fixation, there was non-union in four; bone-grafting had been done in three of these at the time of open reduction. In eight, union was delayed for an average of six months; the shortest time for healing to occur was four months and the longest was eight months. In five of these cases, bone-grafting had been done at the time of fixation. The difficulty in obtaining union

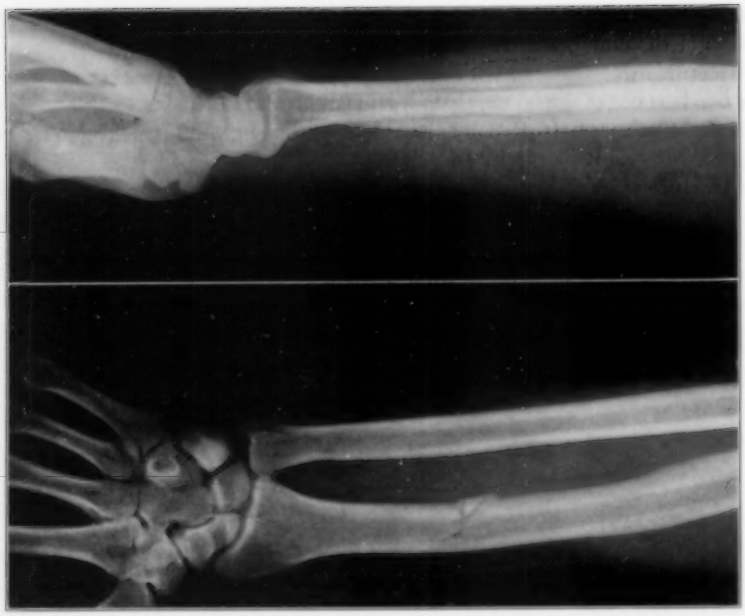

FIG. 6-A

was due to the location of the fracture at the corticocancellous junction of the radius and to the fact that the muscle forces are directed in such a manner that they produce angulation and separation instead of physiological impaction.

FIG. 6-B

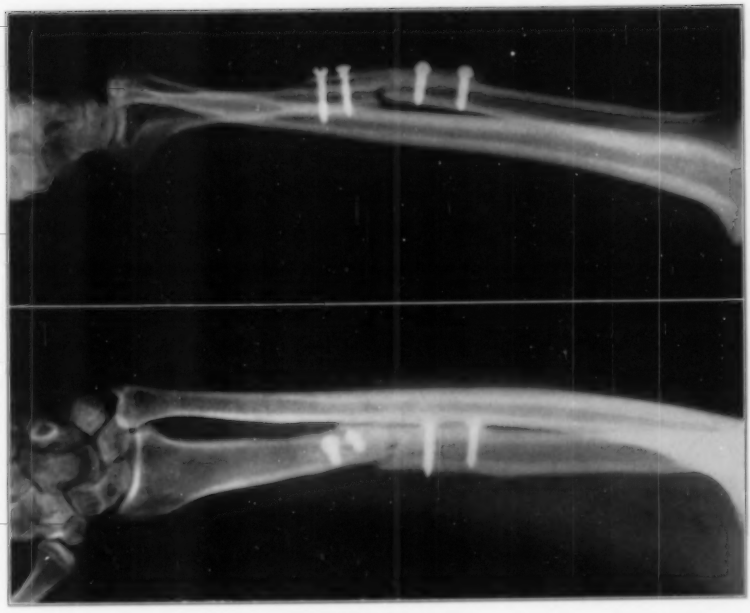

FIG. 7-A

A review of some of the cases will illustrate the difficulties in the treatment of this fracture.

Figure 4-A demonstrates the fresh fracture. Good reduction was obtained (Fig. 4-B). Plaster immobilization of the forearm in neutral position and of the hand resulted in ulnar deviation and displacement of the fracture three weeks later (Fig. 4-C). Transfixation of the distal radial fragment to the ulna (Fig. 4-D) gave inadequate immobilization, but associated fixation of the proximal radial fragment to the ulna produced

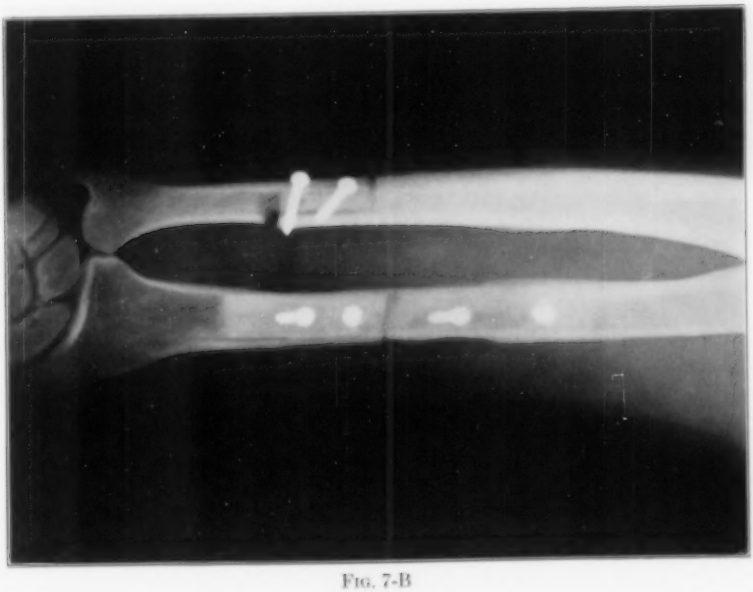

FIG. 7-B

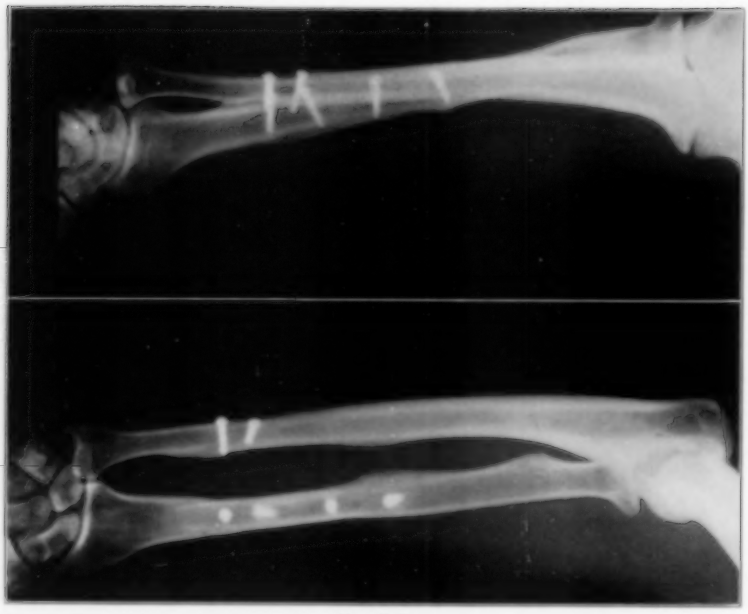

FIG. 7-C

excellent stability at the fracture site. At the same time, the dislocation of the distal radio-ulnar joint was reduced. Cancellous-bone grafting was done and healing occurred in four months. During the four-month period of plaster immobilization, the distal fragment was rotated on the transfixation pin by the deforming forces (Fig. 4-E). Function proved to be poor and excision of the distal portion of the ulna was necessary. Subsequently, good function resulted. When this method of fixation is to be used, two transfixation pins should be placed across the distal fragment in order to prevent rotation.

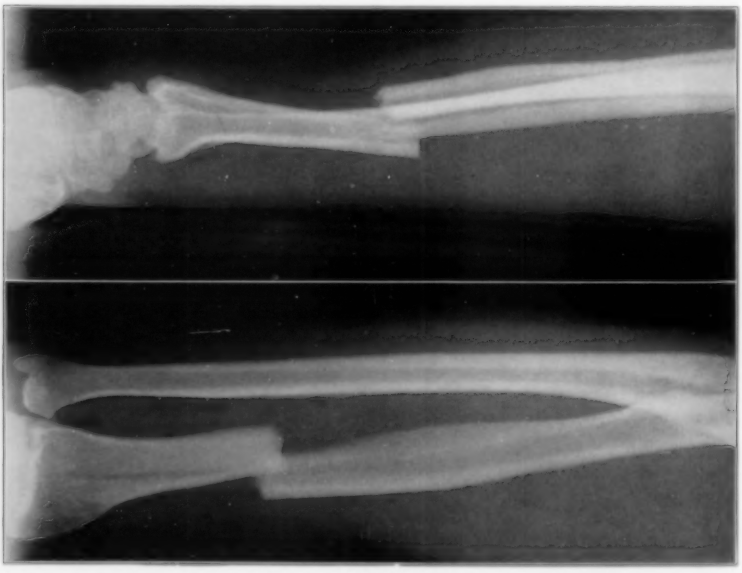

FIG. 8-A

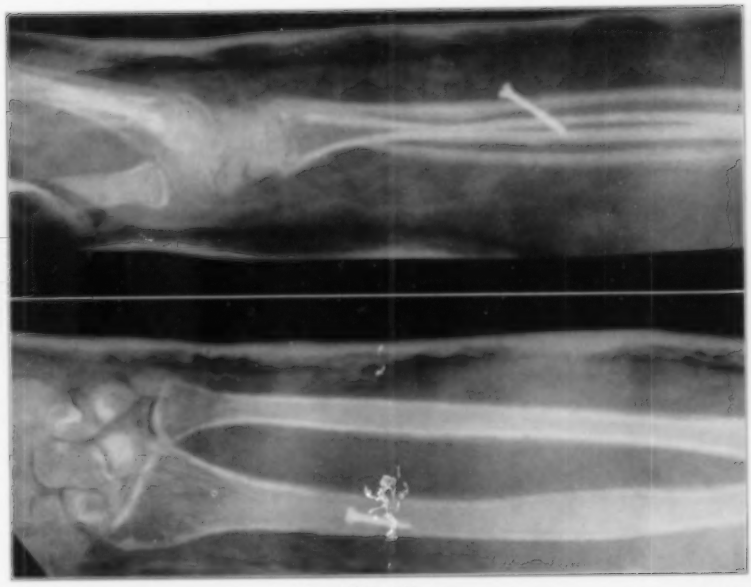

FIG. 8-B

A man had been stabbed through the forearm with an ice pick fifteen years prior to fracture. This had resulted in synostosis of the radius and the ulna in the middle third of the forearm. After a recent fracture of the radius at the junction of the middle and distal thirds (Fig. 5), the deformity associated with this fracture developed during treatment by closed reduction and plaster immobilization.

Figure 6-A shows a fracture in which the fragments were not displaced. It was immobilized, and two weeks later, responding to the deforming forces, subluxation of the distal radio-ulnar joint took place (Fig. 6-B).

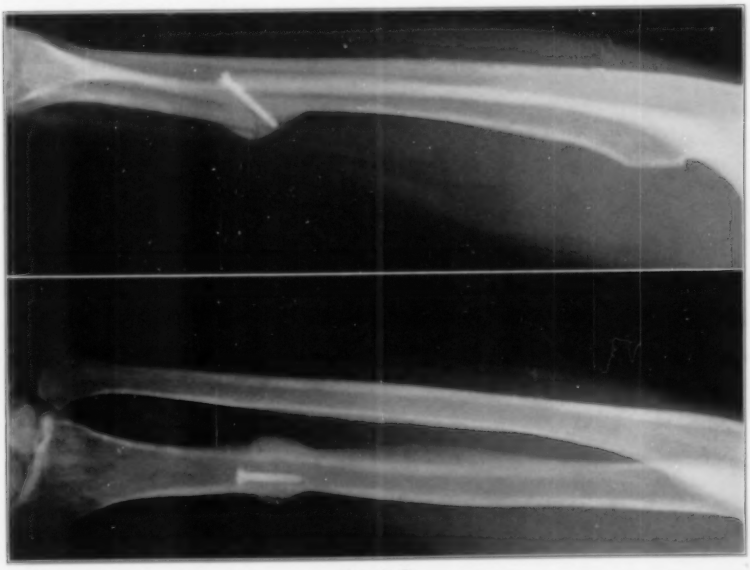

FIG. 8-C

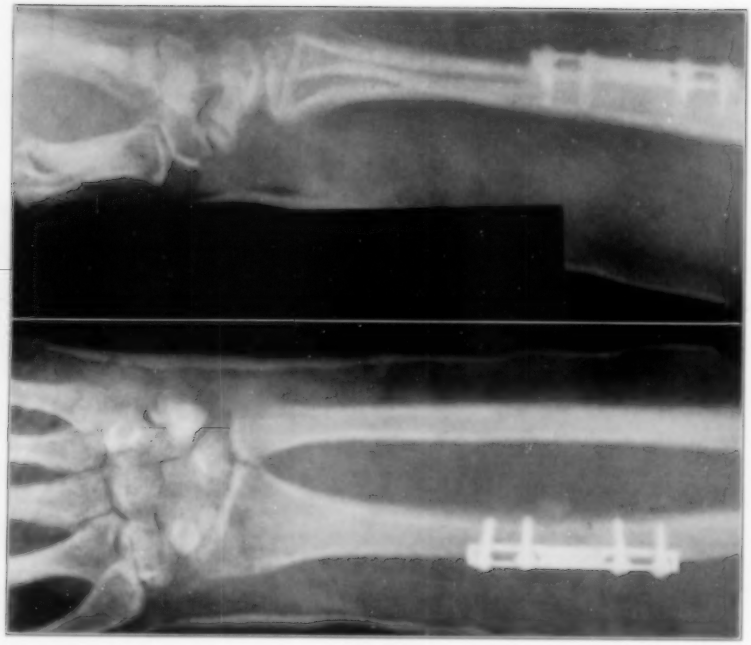

FIG. 9-A

It appears that stability of the proximal fragment of the radius in relation to the ulna is not important in treatment by closed reduction; the muscle forces affecting the proximal fragment do not have to be considered in the treatment of this forearm fracture.

In some of these cases, subluxation of the distal radio-ulnar joint was an immediate result of trauma, but since about 40 per cent of the fractures came secondarily into the

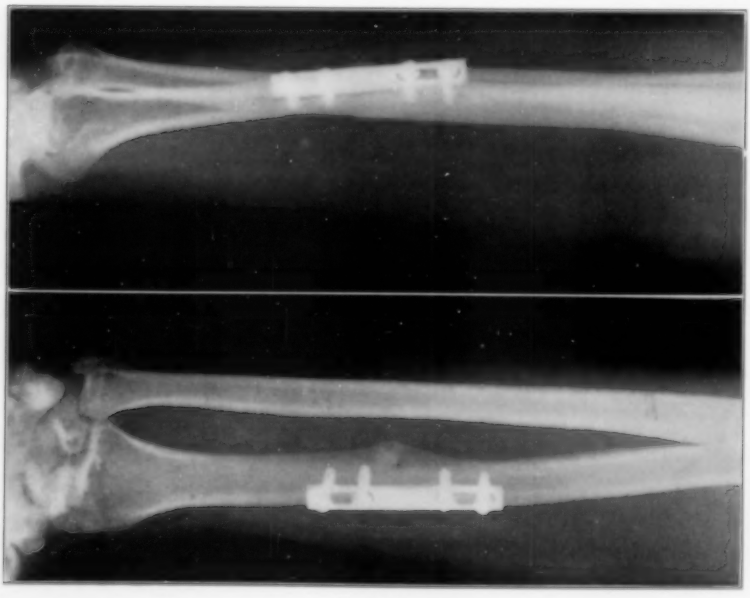

FIG. 9-B

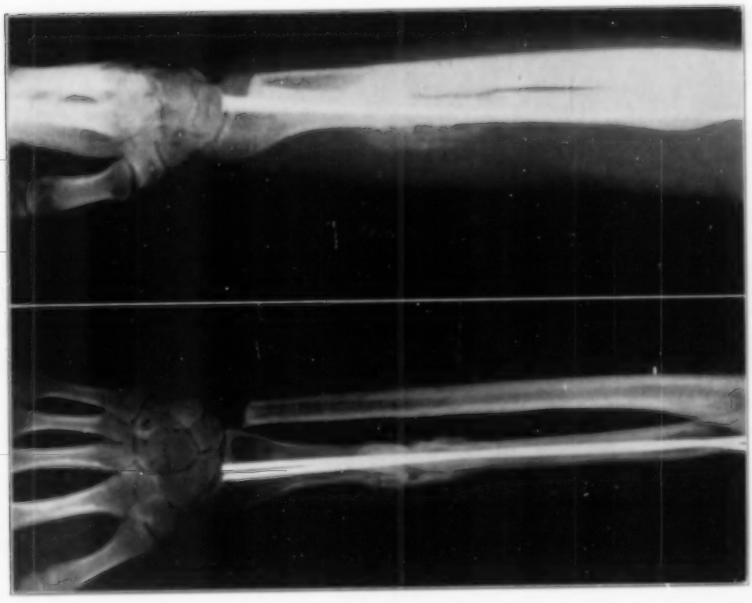

FIG. 10-A

hands of the orthopaedic surgeons, we are unable to state how frequently this occurred. We do know that subluxation eventually occurs as a result of the deforming forces which operate during plaster immobilization.

When open reduction and internal fixation of the radius has been performed and stability at the fracture site has been obtained, the distal radio-ulnar joint should be tested for stability. Because the amount of relaxation present in this joint varies in different individuals, the patient's opposite forearm should be used as a control. If the involved

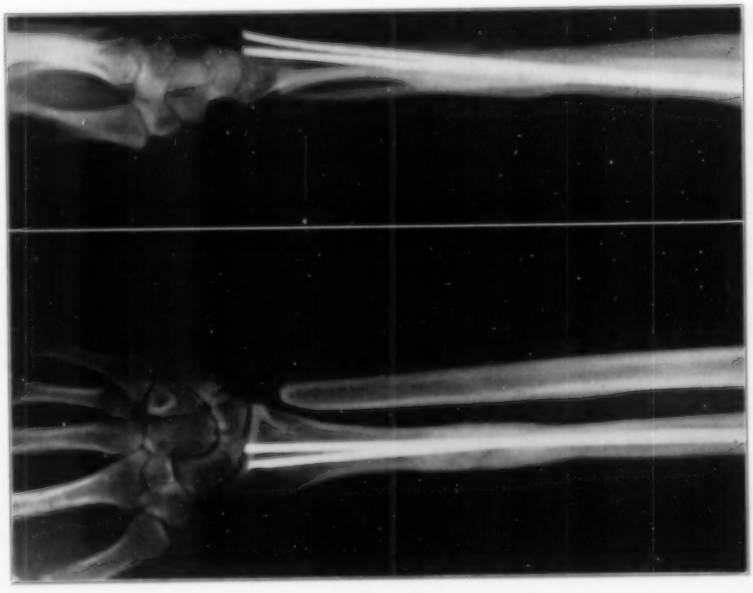

FIG. 10-B

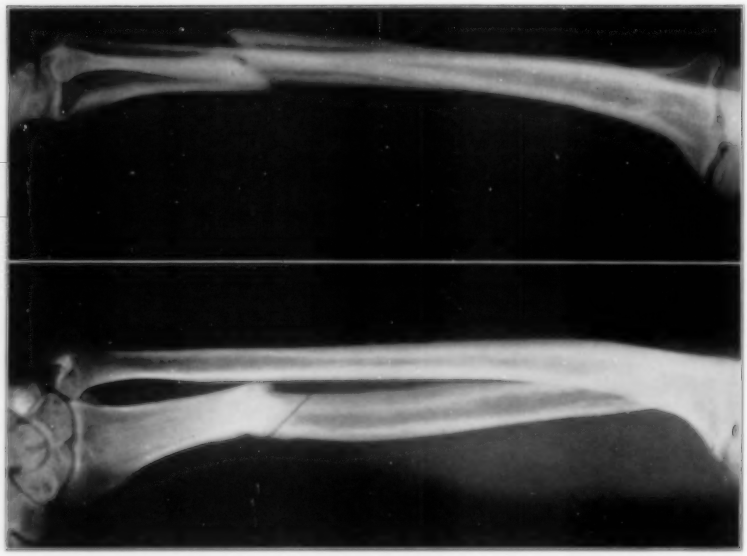

FIG. 11-A

side demonstrates comparative instability, the distal portion of the ulna should be resected. Any amount of absorption at the fracture site, however slight, and any degree of angulation of the radius will produce subluxation of the ulna. When these conditions are observed, immediate resection of the distal portion of the ulna should be done, even while the fracture of the radius is still in the process of healing. Resection of the distal portion of the ulna is almost essential to obtaining a satisfactory result in fractures which are operated upon.

FIG. 11-B

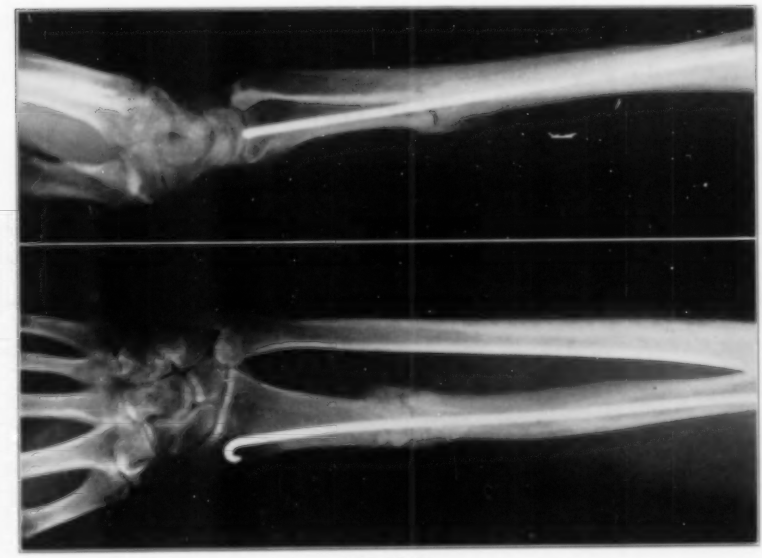

FIG. 11-C

When onlay bone-grafting failed with resultant radial shortening in a fracture treated late (Fig. 7-A), we found that a step-cut shortening of the ulna shaft (Fig. 7-B) was an excellent procedure for reconstruction. However, the slight amount of slipping of the distal fragment of the radius produced enough subluxation of the distal portion of the ulna to prevent excellent function (Fig. 7-C). In this case, there was a 50 per cent limitation of supination at the termination of follow-up, several months after healing.

Screw transfixation across an oblique fracture (Figs. 8-A and 8-B) proved inadequate. Subsequent subluxation of the distal radio-ulnar joint developed and good function was prevented (Fig. 8-C).

Double onlay bone-grafting with fixation by four screws proved to be good operative treatment in the early-treatment group only. In the group of patients treated late it resulted in a high incidence of subluxation of the distal portion of the ulna.

Fixation with a plate and four screws generally proved to be successful. However, in one patient the screws loosened in the cancellous distal fragment and the usual deformity resulted (Fig. 9-B). We are all aware of the difficulty of obtaining consistently good fixation with screws in cancellous bone at any location, but if we consider the osteoporosis of the distal fragment in the patients treated late, we realize the danger resulting from poor screw fixation. This may explain the unsatisfactory results in the patients treated late in whom a double onlay bone graft fixed with four screws was applied.

An old fracture with the usual deformity (Fig. 10-A) was treated by bone-grafting, multiple Kirschner, wire intramedullary fixation, and resection of the distal portion of the ulna. Five months postoperatively there was good union with good function (Fig. 10-B). Intramedullary fixation proved to be successful in the late-treatment group when intramedullary callus had narrowed the canals (Fig. 11-A). One should be cautious, however, in the use of intramedullary fixation in fractures treated early, for the large, funnel-shaped medullary canal of the distal fragment (Fig. 11-B) may allow lateral displacement toward the ulna, and in some oblique fractures, may allow telescoping of the fracture fragments on the pins (Fig. 11-C).

SUMMARY

Fractures of the distal third of the radial shaft are difficult to treat successfully by

means of closed reduction. The early treatment of choice is open operation, anatomical reduction with rigid and secure internal fixation. Resection of the distal portion of the ulna and bone-grafting should be seriously considered in fractures brought to operation three to four weeks after fracture. Restoration of good function in fractures treated late appears to be most successfully accomplished by means of intramedullary fixation combined with bone-grafting of the radius and resection of the distal portion of the ulna.

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DISCUSSION

Dr. Robert Lee Patterson, Jr., New York, N. Y.: I have been able to find only six cases of this isolated and uncommon fracture in a cursory review of the fracture records of the past six years at the New York Hospital. It is amazing that of thirty-eight fractures treated conservatively, thirty-five resulted in failure. The author admits that rather severe criteria of satisfactory and unsatisfactory results have been set up, but it is only by the adoption of stringent standards that there can be accurate appraisal. I think that the discussion concerning the reason reduction is hard to maintain—namely, the weight of the hand and the abnormal muscle pull on the distal fragment—cannot be contradicted. However, I would like to stress that a fracture of the radius at the junction of the middle and lower thirds is very similar to a fracture of the tibial shaft at the junction of the middle and lower thirds. Union in both of these fractures is slow and position is hard to maintain. We had one fracture treated by intramedullary fixation and bone chips in which one year was required for solid union to occur. It is an accepted fact that a fracture of the neck of the femur should be treated by internal fixation. In our clinic, an oblique spiral fracture of the lower end of the tibia is treated with a screw or two screws placed horizontally unless there is some contra-indication. This article by Dr. Hughston convinces me that when fracture of the radius at the junction of the middle and lower thirds is encountered, open reduction with internal fixation is the treatment of choice, unless, of course, there is some contra-indication. It has been our feeling for some time that if surgery is undertaken at the fracture site, either for reduction or fixation, or both, cancellous-bone chips from the ilium should be implanted at the fracture site, whether or not one uses local fixation or an intramedullary type of nail.

One of the drawbacks in the presentation of a series such as this is that although the total number of cases is large—in this series, forty-one—there are multiple methods of treatment of a small number of each type of fracture. Therefore, one cannot draw accurate conclusions based on four fractures fixed with a round intramedullary pin and four fractures fixed with screws. Regardless of the methods of fixation and treatment, one agrees with the author that initial treatment by open reduction and positive fixation gives the best results.

Dr. Marcus J. Stewart, Memphis, Tennessee: This series of cases which has been so well analyzed and reviewed brings to our serious consideration a difficult fracture and its many complications.

I challenge any of you who may be critical and who feel that you have been handling this fracture without difficulty to examine your final results a few years after treatment. You may have obtained solid union, but consider the functional results at wrist, hand, forearm, and elbow.

Sixteen years ago, while I was assisting the late Dr. Willis Campbell in an open reduction and plating of a fracture of the distal radial shaft, he said, "This is a fracture of necessity"—meaning, of course, one which necessitates open reduction and internal fixation. I have never forgotten this remark and its solid advice, nor have I ever seen a good result when this fracture has been treated by manipulation and external immobilization.

It is not only the position in plaster which produces the imbalanced muscle pull and the weight of the hand which produces the displacement and angulation, but resorption at the fracture site with shortening

(Continued on page 402)

A Clinical Evaluation of Operative Procedures for Congenital Talipes Equinovarus*

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The use of surgery to correct congenital talipes equinovarus is not new. Division of the tendo calcaneus to treat club-foot was described by Lorenz in 1784 [9], and lengthening of the tendo achillis was meticulously outlined by Delpech in 1816 [9]. In the 1830's, Stromeyer, who was thoroughly familiar with the work of Delpech, popularized the use of subcutaneous tenotomy in Europe. He also successfully operated on the English surgeon, Little, who in turn enthusiastically advocated use of this procedure in England as a means to control the equinus aspect of club-foot.

As the treatment of club-foot by surgery gained popularity, new and more radical procedures were devised, including operations in which one or more bones were excised in order to control the deformity. Surgeons of stature such as Jones and Elmslie decried such radical procedures, supporting the more conservative approach of forcible manipulation combined with the use of plaster of Paris, a technique introduced by Guerin in the early nineteenth century.

The ensuing controversy split the orthopaedic world into two opposing camps, those supporting the surgical approach and those supporting the conservative approach, considerable material being written by both. In 1951, the continuing dissatisfaction with the operative management of club-foot was summarized by Fripp, who, in his Presidential Address before the Orthopaedic Section of the Royal Society of Medicine in England, suggested that many of the operations used to treat club-foot during the previous fifty years had best be forgotten. As a consequence of this controversy, there is now considerable distrust of the operative measures previously advocated for the correction of congenital talipes equinovarus.

The following presentation is based on a study of fifty-three patients with deformities which could be corrected or controlled only by surgery (it must be emphasized that the majority of patients who receive early and adequate conservative treatment do not need operative treatment). This group of patients was drawn from a series of about 150 patients with congenital club-foot deformity treated during the thirty-year period from 1924 to 1954, in the orthopaedic clinics of the Vermont Crippled Children's Services.

In this series the ratio of operative to non-operative cases is inordinately high, for most of the children seen in the orthopaedic clinics of the Crippled Children's Services are referred to these clinics because of resistant or recurrent deformities or because their conditions have been neglected. Furthermore, during much of the period included in this study, especially during World War II, facilities for effective conservative treatment were not available in many parts of Vermont. It was, therefore, necessary in many instances to resort to definitive operative treatment in order to bring under control, as promptly as possible, a severe club-foot deformity.

Because a variety of procedures were used in this series and because relatively long follow-up was possible, the authors feel justified in presenting the following analysis of the results obtained by some of the more common operative procedures used in the surgical treatment of club-foot.

* Read in part at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, February 1, 1956.

MATERIAL

In this series of fifty-three patients, there were seventy-eight congenital club feet upon which operations were performed. Among these fifty-three patients there were almost three times as many boys as girls. The number of bilateral deformities was practically the same as the number of unilateral deformities. Of the twenty-nine patients with bilateral deformities, only four did not require operations on both feet (Chart I).

In order to obtain a more accurate evaluation of the results, patients with deformities which resulted from neurological disorders or which accompanied primary aplasia of connective tissue and muscle were excluded from this study. In the remaining patients the congenital club-foot deformity either was resistant to non-operative correction or persistently recurred following treatment.

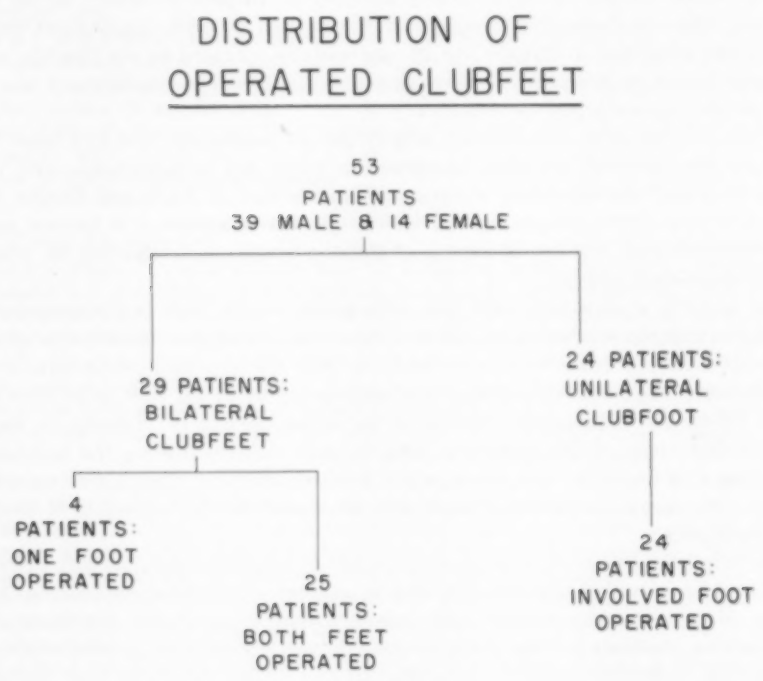

CHART I

One hundred and fifty-four operations were performed upon these relatively few patients (Chart II). The operative procedures were of two types. The majority (136 operations) were designed to alleviate the ill effects of tight ligamentous and tendinous structures as well as to eliminate the pull of active deforming elements (Chart III). The remaining operations (eighteen) were designed to correct skeletal deformity (Chart IV). The average age at which the soft-tissue procedures were done was four and one-half years, while the average age at which the bone operations were done was just under ten years.

An effective follow-up program was possible through the cooperation of the orthopaedic clinics of the Crippled Children's Services of the Vermont State Department of Health; these clinics have been functioning actively over the past forty years. The mean period of observation following surgery was 7.7 years (Chart V). As a result of this follow-up program, it was possible to obtain definite clinical impressions regarding the value of certain operative procedures for the correction of congenital talipes equinovarus.

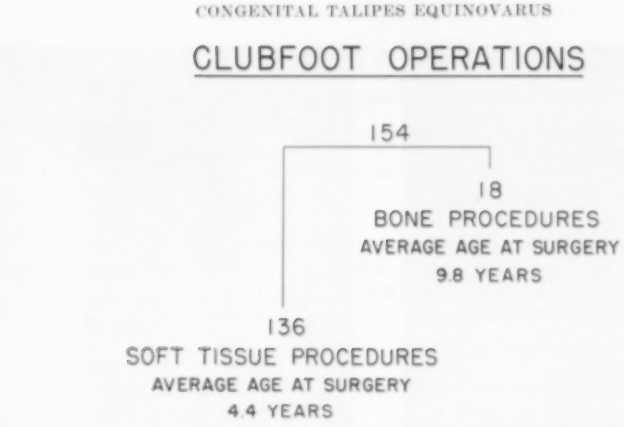

CHART II

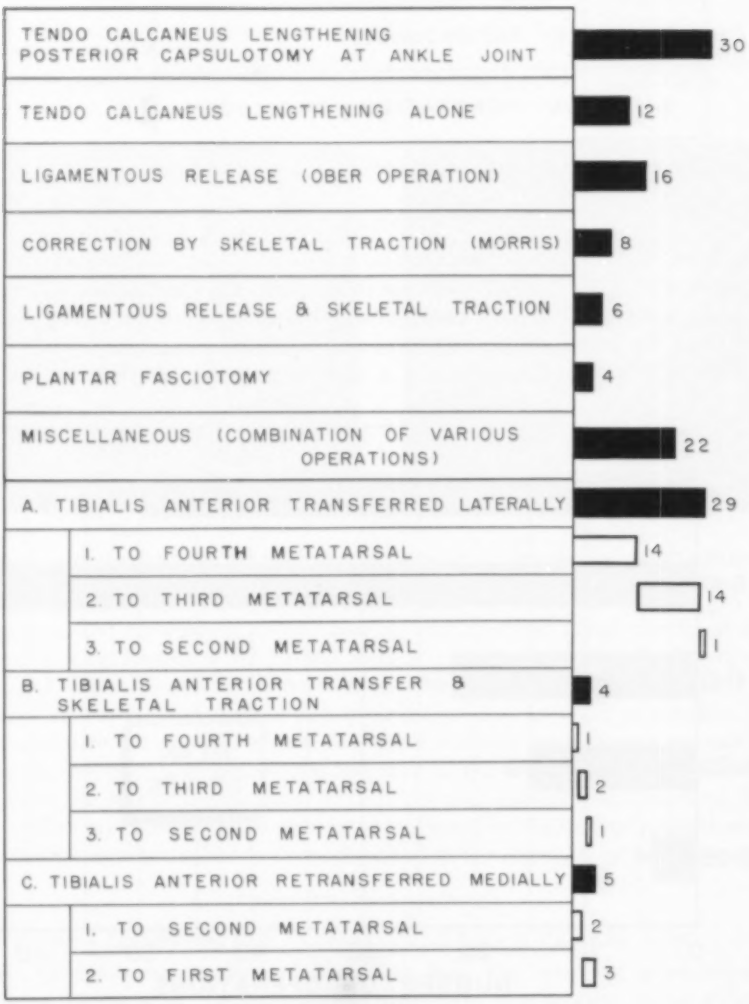
TENDO CALCANEUS LENGTHENING POSTERIOR CAPSULOTOMY AT ANKLE JOINT 30
TENDO CALCANEUS LENGTHENING ALONE 12
LIGAMENTOUS RELEASE (OBER OPERATION) 16
CORRECTION BY SKELETAL TRACTION (MORRIS) 8
LIGAMENTOUS RELEASE & SKELETAL TRACTION 6
PLANTAR FASCIOTOMY 4
MISCELLANEOUS (COMBINATION OF VARIOUS OPERATIONS) 22
A. TIBIALIS ANTERIOR TRANSFERRED LATERALLY 29
1. TO FOURTH METATARSAL 14
2. TO THIRD METATARSAL 14
3. TO SECOND METATARSAL 1
B. TIBIALIS ANTERIOR TRANSFER & SKELETAL TRACTION 4
1. TO FOURTH METATARSAL 1
2. TO THIRD METATARSAL 2
3. TO SECOND METATARSAL 1
C. TIBIALIS ANTERIOR RETRANSFERRED MEDIALLY 5
1. TO SECOND METATARSAL 2
2. TO FIRST METATARSAL 3

CHART III

Soft-tissue operations (136).

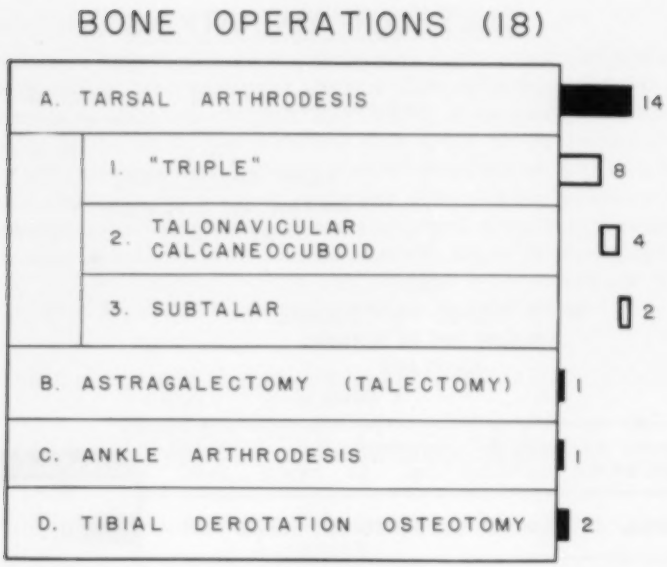

CHART IV

RESULTS

Evaluating the results of any operative procedure is admittedly difficult. Factors such as the severity of the deformity, the age of the patient at the time of the initial treatment, and the social and environmental circumstances are significant. In this study the degree to which the final result was obtained by the specific operation or combination of operative procedures was determined by a detailed appraisal of all available clinical,

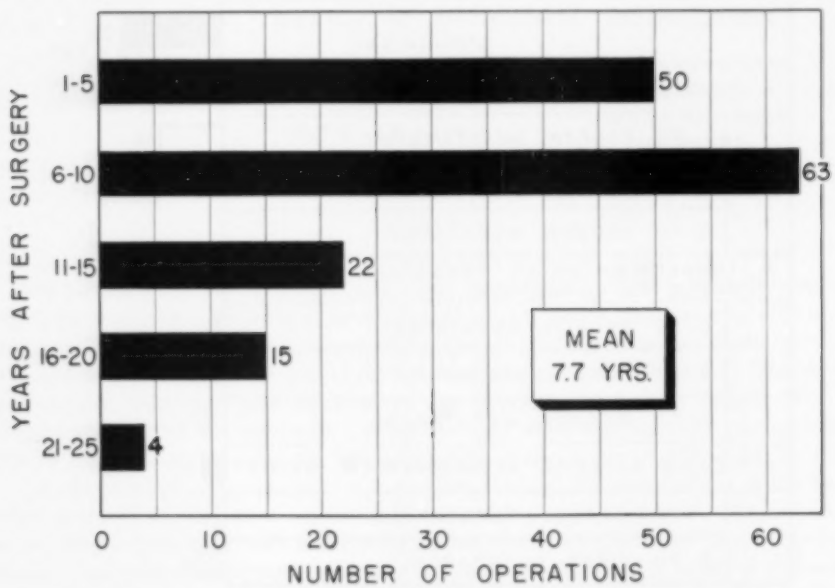

CHART V

Follow-up record of 154 club-foot operations.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Congenital talipes equinovarus deformity of the right foot in a five-month-old infant. Previous treatment had been inadequate.

▶ Fig. 1-B: Heel-cord lengthening and posterior capsulotomy were done when the patient was one year old. During the previous seven months good correction of the other club-foot elements had been achieved by means of casts. This photograph was made when the patient was three.

FIG. 1-C

FIG. 1-D

These photographs, made two years after surgery, demonstrate that the postoperative range of passive motion of the ankle was from 20 degrees of dorsiflexion to 35 degrees of plantar flexion.

photographic, and roentgenographic material, this material being correlated with the findings of an examination of the patient made in order to determine the functional, anatomical, and cosmetic result. To make these findings meaningful, it was necessary to use a descriptive approach rather than a purely statistical one. In order to tabulate the data and to emphasize the anatomical and functional findings, an arbitrary evaluation scale was used; in this scale *poor* represented less than 25 per cent reduction of the deformity; *fair*, 25 to 50 per cent reduction; *good*, 50 to 75 per cent reduction; and *excellent*, 75 to 100 per cent reduction. The operative techniques employed in the various surgical procedures evaluated were usually similar to those described in the standard orthopaedic texts.

SOFT-TISSUE OPERATIONS

Tendo Calcaneus Lengthening with Posterior Capsulotomy of the Ankle Joint

This operation was performed on thirty feet, the resulting good-plus-excellent rating being 73 per cent. In the patients with slight preoperative varus deformity of the heel, this procedure was augmented by simple capsulotomy of the medial aspect

of the subtalar joint. The average age at which the operation was performed was 2.4 years.

The operation proved to be an effective means of alleviating persistent equinus deformity of the hind portion of the foot (Figs. 1-A through 1-D). The use of a retention apparatus, particularly at night, with an occasional period in corrective casts to obtain stretching, seemed necessary to maintain the improved position of the foot. No significant loss of motor power in the gastrocnemius-soleus group was apparent (Figs. 2-A and 2-B). With surprising regularity, however, there was some loss of plantar-flexion motion at the involved ankle joint. The usual range of ankle motion following heel-cord lengthening and posterior capsulotomy was from 10 degrees of dorsiflexion to 30 degrees

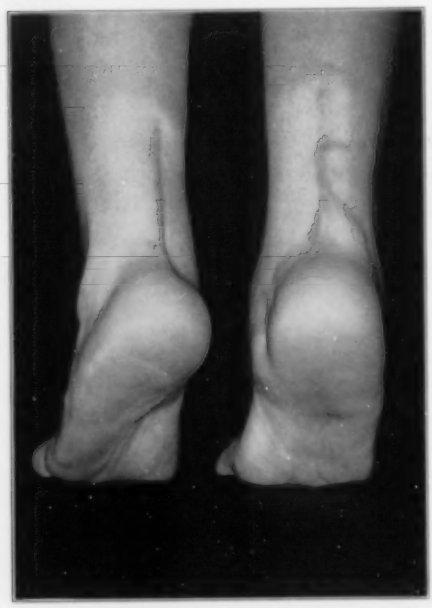

FIG. 2-A

FIG. 2-B

Figs. 2-A and 2-B: Bilateral heel-cord lengthening and posterior capsulotomy were done when the patient was one year old. Subsequently, when the patient was twelve and one-half years old, heel-cord lengthening and triple arthrodesis were done on the left foot. Following treatment, the patient had a strong tiptoe gait, and there was no gastrocnemius-soleus weakness in either foot. These photographs were made when the patient was twenty.

of plantar flexion. The restriction of plantar flexion appeared functionally insignificant, for the postoperative range of motion was in a more useful arc, resulting in improvement in the patient's gait (Figs. 1-C and 1-D).

Tendo Calcaneus Lengthening Alone

In twelve cases simple heel-cord lengthening was done to correct equinus deformity of the hind portion of the foot. The average age at which the operation was performed was one year. There was no appreciable loss of muscle power in the gastrocnemius-soleus group following the operation, and the procedure was found to be an effective means of correcting persistent equinus of the heel. Although, as the good-plus-excellent rating of 50 per cent indicates, this operation alone was not quite as effective as it was when combined with posterior capsulotomy at the ankle joint, it did have the advantage of causing less loss of plantar motion at the ankle joint. In this procedure, as in the procedure previously described, the use of a retention apparatus was necessary to achieve a good final result.

FIG. 3-A

FIG. 3-B

Figs. 3-A and 3-B: Bilateral congenital talipes equinovarus in a two-year-old child. The deformity of the left foot is more severe than that of the right. These photographs were made before treatment.

FIG. 3-C

FIG. 3-D

Figs. 3-C and 3-D: Heel-cord lengthening and posterior capsulotomy were done bilaterally when the patient was two. Following this, skeletal traction was used on the left foot to control the position of the heel. When the patient was three, the tibialis anterior tendon was transferred to the fourth metatarsal in the left foot and to the third metatarsal in the right foot. These photographs were made when the patient was four.

Release of Ligamentous Structures on the Medial Aspect of the Foot

In sixteen cases the operative procedure described by Ober was used to correct persistent varus deformity of the foot. The average age at the time of operation was 3.8 years. The good-plus-excellent rating in this series was 31 per cent in contrast to the 80 per cent good and excellent results in the series of fifteen cases reported by Heyman in 1929. Although the operation achieved a good initial correction of the varus and adduction deformity and although efforts were made to retain that correction, recurrence was common between the first and second years following surgery. In ten of the sixteen cases,

subsequent operative procedures were required in order to achieve a more permanent correction of the club-foot deformity.

Occasionally some of the apparent correction of the varus deformity was the result of tilting of the talus at the ankle joint. In some cases the vigorous and extensive stripping of the soft tissues necessary in this method of ligamentous release was followed by rigidity of the foot and ankle, associated with nutritional disturbance in the growing bone. It is emphasized that this procedure was employed most frequently in patients with neglected deformities or with severe recurrent deformities. The operation was of benefit to the patient in that it resulted in the deformed foot being held in a reasonably satisfactory weight-bearing position until such time as further definitive surgery could be performed.

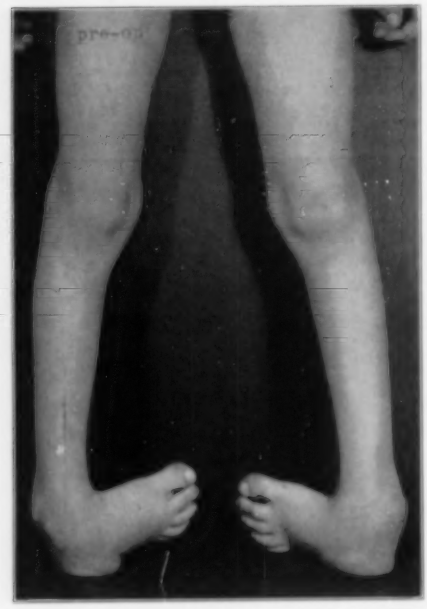

FIG. 4-A

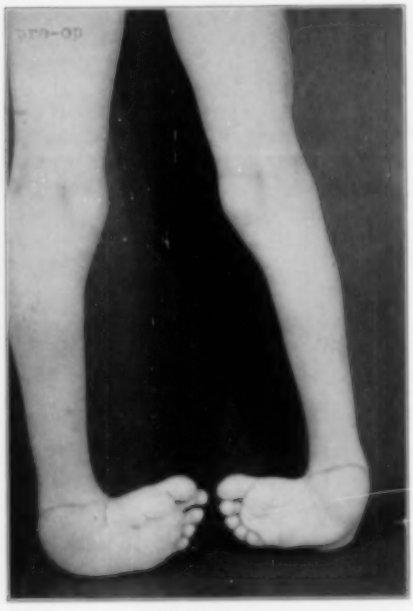

FIG. 4-B

Figs. 4-A and 4-B: Severe bilateral congenital talipes equinovarus in a patient aged six and one-half. This patient was subsequently treated by ligamentous release and skeletal traction. Further treatment was refused.

Skeletal Traction

Stretching of the tight medial and posterior structures of the foot and ankle was obtained by means of an ingenious apparatus described by Morris in 1943. By this effective skeletal-traction device, powerful leverage was gradually exerted upon the tight and deforming soft-tissue structures. Despite the obvious advantages of this method, however, only fair end results were obtained in the eight cases in which it was employed as the sole means of treatment. As occurred following the ligamentous-release operation, the initial correction was good but recurrence of the deformity was common. This method is nevertheless of value, particularly when combined with other procedures, for it can be used to obtain temporary control of a difficult deformity (Figs. 3-A through 3-D).

Ligamentous-Release and Skeletal-Traction Procedures Combined

The deformities in this group of six cases were more severe or more resistant to correction than the deformities in the other categories (Figs. 4-A and 4-B). This may explain in part the fact that despite the effectiveness of the combined procedures, the results were

no better in this group than in the others; in fact, two of the results were classified as *poor* because of recurrence of the deformity. In this group, as in the preceding group, the immediate postoperative result was good but recurrence of the deformity was common.

Plantar Fasciotomy

Occasionally in plantar-flexion deformity the cavus element is a prominent feature. In four such cases plantar fasciotomy was done, following which a series of corrective casts were applied. Contrary to general opinion, it was found that simple, open, complete fasciotomy assisted significantly in controlling the cavus element of the progressive deformity. Admittedly, however, this procedure was useful only as an adjunct.

Lateral Transplantation of the Tibialis Anterior Tendon

In twenty-nine cases the tibialis anterior tendon was transferred laterally to correct varus deformity. The average age of the patient at the time of the operation was five years. In twenty-eight cases the transposed tendon was inserted into the third or fourth metatarsal, and in the remaining case it was inserted into the second metatarsal.

The good-plus-excellent rating in this series of twenty-nine cases was 86 per cent (twenty-five cases). The operation reduced the varus deformity of the fore part of the foot by improving the balance in the extensor-evertor musculature while at the same time removing an active deforming element. In many cases functional weakness of the evertor musculature of the foot was apparent preoperatively, and on several occasions, anomalous insertion of the tibialis anterior tendon was encountered at operation, a finding which other authors have also reported.

Improvement was not as a rule immediate, but with time the varus deformity decreased as a result of the active corrective force exerted by the transferred tibialis anterior tendon. The tendon was transferred to the third and fourth metatarsals an equal number of times. In two of the fourteen cases in which it was placed in the fourth metatarsal, valgus deformity developed. When the tendon was retransferred to the second metatarsal, however, a good-to-excellent result was obtained. Overcorrection also occurred in the two instances in which the tibialis anterior was transplanted just lateral to the mid-portion of the foot, skeletal traction being used as an adjunct procedure. The resulting valgus deformity required replacement of the transferred tendon to the point of initial origin at the first metatarsal. In one patient, valgus deformity developed following transfer of the tendon to the third metatarsal, requiring relocation of the tendon in the first metatarsal-cuneiform area. In this patient shifting of the tibialis posterior to the neck of the talus, in conjunction with tarsal capsulotomy, was also done. The strength of the transferred tibialis anterior was not altered by the relocation of its insertion (Figs. 5-A through 5-F).

Miscellaneous Soft-Tissue Operations

This group includes a number of soft-tissue procedures which were performed upon only a few patients. Because follow-up in each case was reasonably long, it would seem that the clinical observations made concerning these operations can be considered valid.

Neurectomy of the medial plantar nerve to the abductor hallucis longus with lengthening of the abductor hallucis longus and tibialis posterior: In a very limited number of cases, this procedure was used successfully to treat persistent adduction of the first metatarsal, a condition which partially caused adduction deformity of the fore part of the foot. In properly selected cases this procedure, or portions of it, should be of value.

Tendo calcaneus lengthening with posterior capsulotomy and skeletal traction: This procedure was used successfully to correct resistant equinus deformity of the hind portion of the foot. It was particularly useful in holding either a very pudgy or a very small heel in the corrected position.

FIG. 5-A

FIG. 5-B

Untreated bilateral congenital talipes equinovarus in a two-year-old boy.

FIG. 5-C

FIG. 5-D

Tendo calcaneous lengthening and posterior capsulotomy were done bilaterally for persistent equinus when the patient was two. When the patient was three, the tibialis anterior was transferred bilaterally to the fourth metatarsal in order to control the varus deformity. These photographs were made when the patient was six.

FIG. 5-E

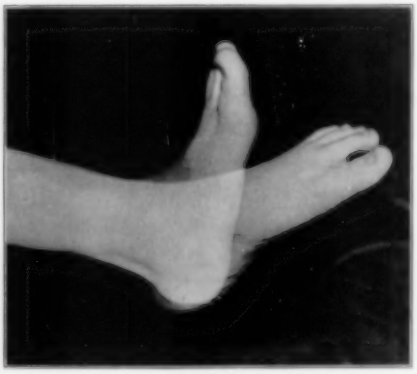

FIG. 5-F

These composite photographs, made when the patient was six years of age, demonstrate the action, bilaterally, of the relocated tibialis anterior tendons.

FIG. 6-A

FIG. 6-B

Fig. 6-A: A preoperative lateral roentgenogram, made when the patient was five years old, showing congenital talipes equinovarus deformity of the right foot.

Fig. 6-B: A similar lateral roentgenogram made when the patient was seven and one-half years old. Subtalar arthrodesis had been done when the patient was five and one-half, and triple arthrodesis had been done when he was seven. Note the appearance of the talus.

Fig. 6-C: Roentgenogram of the same foot, made four and one-half years later, when the patient was twelve. The talus had been absorbed into the calcaneous, and the navicular articulates with the anterior surface of the tibia. The area of decreased density in the proximal portion of the fifth metatarsal is of undetermined origin.

FIG. 6-C

FIG. 6-D: Photograph of the two feet made at the same time as the roentgenogram in Fig. 6-C. The patient needs mismated shoes, and there is a loss of height of five-eighths of an inch in the right foot as compared with that in the left. Some varus deformity remains.

FIG. 6-D

Tendo calcaneus lengthening with lateral transplantation of the tibialis anterior tendon: The deformity was well controlled in the few patients upon whom this combination of operative procedures was done. The tibialis anterior tendon should not, of course, be transferred in the presence of a tight tendo achillis.

Other procedures: In selected single cases division of specific tight structures, such as the abductor hallucis longus, the tibialis posterior, and, on occasion, the ligamentous and capsular structures of the talonavicular joint, yielded immediate benefit. In all these cases, however, additional procedures were necessary to produce good final results.

BONE OPERATIONS

In this numerically small group, the most common operation used was fusion of the

tarsal area. This group of operations demonstrates the effectiveness of therapy which is directed toward the permanent stabilization of a progressive deformity. When the proper technique was used and when the arthrodesis was done at the time that the bone of the growing foot reached maturity, an excellent result was obtained. When the arthrodesis was done before the age of eight years, while the bone was still immature, the resulting foot, which did not continue to grow properly, eventually became smaller than the other foot and reoperation was usually necessary in order to control the deformity (Figs. 6-A through 6-D).

Derotation osteotomy of the tibia in the occasional patient with residual internal tibial torsion yielded gratifying functional and cosmetic results (Figs. 7-A through 7-C).

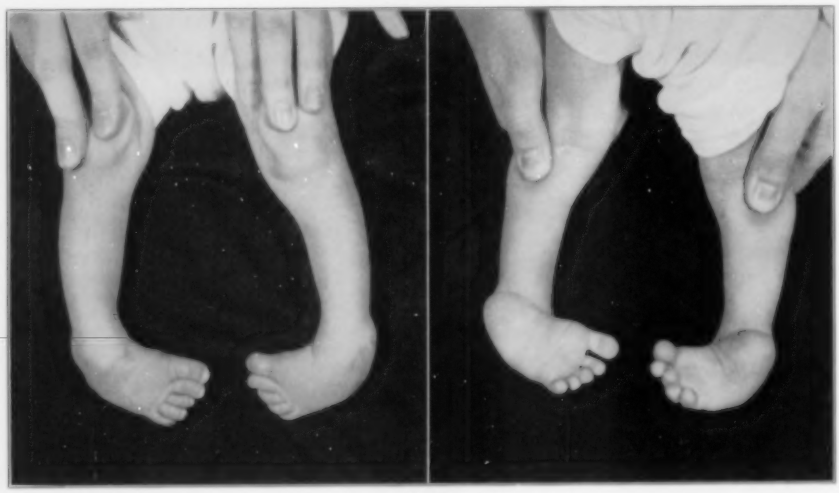

FIG. 7-A

Bilateral congenital talipes equinovarus in an infant aged three and one-half months. There is prominent medial tibial torsion of both feet.

FIG. 7-B

Moderate correction of the equinus and varus elements was obtained by the time the patient was eighteen months of age. Adduction of the fore part of the foot and medial tibial torsion persisted bilaterally.

FIG. 7-C

Heel-cord lengthening and posterior capsulotomy, followed by transplantation of the tibialis anterior to the third metatarsal, were done bilaterally when the patient was three. The in-toeing gait, which persisted because of the medial tibial torsion, was corrected by the performance of derotation osteotomy (O'Donoghue type) of both tibiae when the patient was seven. This photograph shows the result when the patient was eleven.

The procedure was performed only after adequate correction of the other deforming elements had been obtained.

COMMENTS

Successful treatment of club-foot depends upon early and adequate correction followed by the prevention of recurrence.

FIG. 8-A

Fig. 8-A: Anteroposterior roentgenogram of the right foot of a sixteen-year-old girl who had had congenital talipes equinovarus. When the patient was two years of age, manipulation had been done (a general anaesthesia being used), following which corrective casts had been applied. Note the residual medial displacement of the navicular, the lateral projection of which has been compressed, probably as a result of contact with the second and third cuneiform bones.

Fig. 8-B: This lateral roentgenogram, also made when the patient was sixteen, shows the deformity of the anterior portion of the talus and contiguous portions of the navicular and the early traumatic arthritic changes at the talonavicular and navicular-cuneiform joints. Early tendo calcaneus lengthening might have prevented these changes.

FIG. 8-B

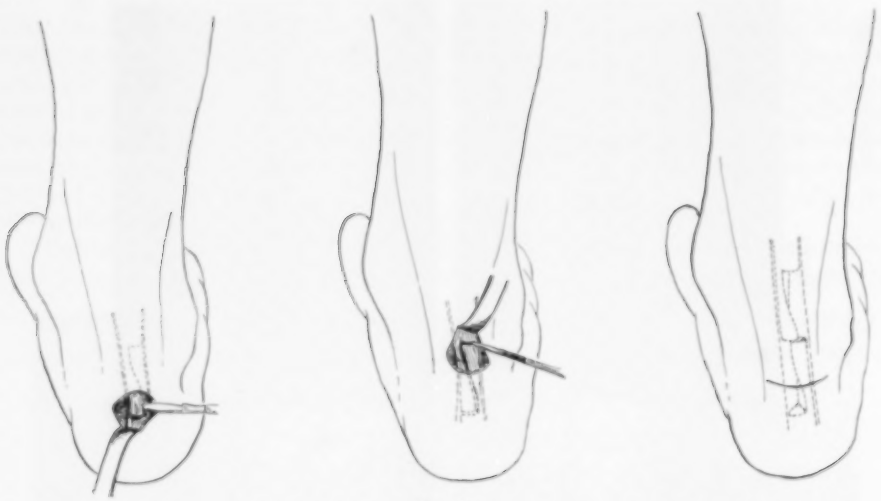

FIG. 9

A method of tendo calcaneus lengthening for correction of club-foot deformity in infants (up to fifteen months of age).

Left: A short transverse incision is made one centimeter above the insertion of the tendo calcaneus. Following retraction of the lower margin of this incision, which exposes the ends of the medial fibers within the sheath, the posteromedial half of the tendon is divided transversely. The tenotome is then turned to start the longitudinal component of the Z-cut in a proximal direction. At the start of this cut, the blade of the tenotome lies in an oblique plane through the tendon from the posterolateral toward the anteromedial aspect. In order to parallel the direction of the fibers as they twist in the tendon, the tenotome is directed proximally in a spiral fashion so as to separate rather than to divide the fibers. At the proximal end of the longitudinal cut, the tenotome lies in a plane from the posteromedial to the anterolateral aspect. The length of this cut depends upon the amount of lengthening needed to correct the deformity, which is usually 1.5 to 2.5 centimeters. The necessary exposure is obtained by gradually shifting the retraction of the skin proximally.

Center: The Z-cut is completed by transversely dividing the posterolateral fibers of the tendo calcaneus which are exposed by retraction of the superior margin of the skin incision. In this procedure, it is possible to preserve the tendon sheath to a considerable extent. This is done by making stab wounds in the sheath through which a small tenotome is inserted to divide the underlying tendo achillis in the described manner.

Right: At the completion of this procedure, the ends of the divided tendo calcaneus lie in contact with each other within the tendon sheath. No suture material is used except to close the skin incision.

FIG. 10-A

FIG. 10-B

Figs. 10-A and 10-B: Overcorrection of the congenital club-foot deformity in the right foot occurred following treatment by capsulotomy of the talonavicular joint, transplantation of the tibialis posterior to the neck of the talus, and transplantation of the tibialis anterior to the third metatarsal. Overcorrection of the deformity of the left foot occurred following treatment by capsulotomy, lengthening of the tibialis posterior and sections of the origins of the flexor digitorum brevis and the great toe abductor, and neurectomy of the medial plantar nerve innervating the abductor hallucis. Other procedures also done on the left foot were transplantation of the tibialis anterior to the third metatarsal and skeletal traction. These procedures were performed when the patient was between two and one-half and three years of age. The photographs were made when he was nine and one-half, just prior to bilateral retransplantation of the tibialis anterior to the first metatarsal-cuneiform area. Triple arthrodesis will be required when the patient is older.

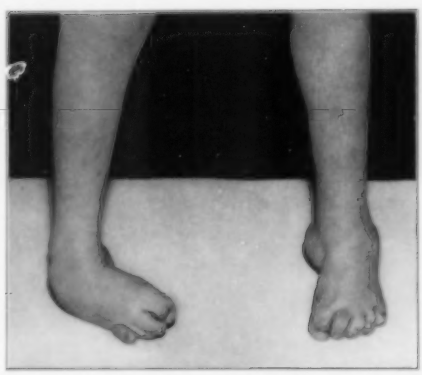

FIG. 11-A

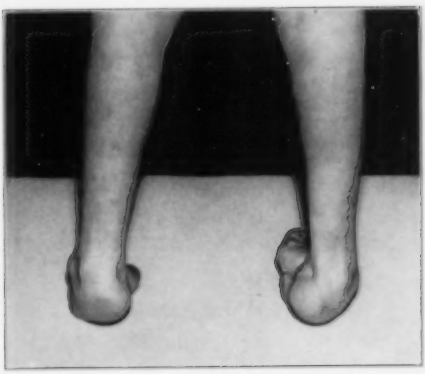

FIG. 11-B

Figs. 11-A and 11-B: Bilateral congenital talipes equinovarus in a six-year-old child. Early treatment by casts and braces was followed by recurrence of the deformity.

FIG. 11-C

FIG. 11-D

Figs. 11-C and 11-D: These photographs were made one year after surgery. This surgery included, in the left foot, tendo calcaneus lengthening and posterior capsulotomy, and in the right foot, ligamentous release, tendo calcaneus lengthening, and posterior capsulotomy with subsequent transplantation of the tibialis anterior to the third metatarsal-cuneiform area. Triple arthrodesis of the right foot will probably be necessary later.

As has been previously emphasized, the use of such conservative measures as casts, splints, exercises, and braces is, in most cases, entirely sufficient to obtain and maintain optimum correction. In some cases, however, the severity of the deformity or the persistent recurrence of one or more of the equinovarus elements makes the use of operative measures desirable as adjunct treatment.

From this study the authors believe that certain types of operation are helpful in achieving and maintaining correction. Heel-cord lengthening is an effective procedure to control resistant equinus deformity, and muscle imbalance can often be improved by such procedures as lateral transplantation of the tibialis anterior tendon. Ligamentous and bone procedures also have their value, and their use should be considered whenever they will help attain anatomical and functional improvement. The degree of severity of the original deformity, the amount of resistance to correction of any of the club-foot elements, and the age of the patient are factors which must be taken into consideration in the selection of an appropriate method of treatment. In severe deformities it may be impossible to

achieve a satisfactory result without surgical assistance; even in younger patients conservative measures may sometimes prove inadequate.

It must not be assumed, however, that any single radical operation will successfully eliminate all the elements of club-foot deformity. Each surgical procedure should be designed to achieve a limited goal within the over-all corrective program. During the period of correction several operations may be necessary in order to control a deformity which tends to increase with growth, and in this series a considerable number of the patients required two, three, and even four surgical procedures.

In this group of cases heel-cord lengthening, with or without capsulotomy of the posterior aspect of the ankle joint, proved a useful operation. To some surgeons, failure to correct a persistently tight tendo achillis by adequate stretching is tantamount to a lack of skill. We feel, however, that it is more realistic to regard heel-cord lengthening as a simple procedure frequently effective in preventing rocker-bottom deformity of the foot. Relentless insistence upon forcing the resistant foot into a mold which it will not easily assume may be more harmful than the early performance of heel-cord lengthening (Figs. 8-A and 8-B).

Lengthening of the tendo achillis in an infant may be done with minimal trauma if a short transverse incision is used (Fig. 9). In order to retain the integrity of the sheath surrounding the heel cord, the latter should be divided by means of a very small knife blade inserted through stab wounds in the sheath. To avoid further trauma and foreign-body reaction, no effort should be made to suture the ends of the divided tendon. The natural reparative properties of the tendon will re-establish its continuity, particularly if the ends are in contact within the preserved tendon sheath. It is felt that during infancy, four to six weeks of immobilization in a toe-to-groin plaster cast with the foot in a neutral position is adequate. Following this a walking cast or brace should be used to further protect the tendon until satisfactory function has been restored. This type of procedure has limited usefulness, of course, being most effective in infants with resistant equinus due to a tight heel cord. It has the advantage of causing less scarring of the skin and underlying tissues than the conventional types of heel-cord lengthening.

As has been demonstrated in the review of the individual cases, heel-cord lengthening with or without capsulotomy is merely one step in the total program. It is also necessary to maintain the correction, which can be done by means of either plaster casts bivalved for night wear or an apparatus which will keep the tendo calcaneus stretched out, particularly during the sleeping hours. Passive and active foot exercises and the wearing of proper shoes are additional important features of the correction program.

In this series transfer of the insertion of the tibialis anterior to the second, third, or fourth metatarsal was found to be valuable in controlling varus deformity of the foot. The selection of the site of insertion was made on the basis of the strength of the lateral toe extensor and evertor musculature as well as on the basis of the severity of the deformity. In this operation, by which a strong deforming element is converted into an active correcting force, all criteria for tendon transplantation must be observed. The effectiveness of the pull of the transferred tendon was demonstrated in this series by the several cases in which overcorrection occurred and retransfer of the tendon to its original insertion was required. Overcorrection was particularly prominent when the transplantation of the tibialis anterior was accompanied by the performance of vigorous soft-tissue procedures upon the medial aspect of the foot (Figs. 10-A and 10-B). On the basis of this series, the authors would recommend that the tibialis anterior be transferred laterally no farther than the fourth metatarsal; furthermore, they have found that the transferred tendon can function effectively in the area of the second metatarsal, depending upon the strength of the evertor musculature and the severity of the deformity.

Among the procedures designed to combat persistent adduction deformity, neurectomy of the medial plantar nerve to the abductor hallucis, done in association with

lengthening or division of the origin of the abductor hallucis and the short toe flexors, was found to be especially promising. Since it was used in only a few cases, however, final evaluation cannot be made.

The additional soft-tissue procedures discussed, that is, ligamentous release, skeletal traction, and combinations of the two, with or without associated soft-tissue operations, were helpful in obtaining good initial corrections. One to two years after these operations, however, the deformity almost invariably recurred, making further surgery necessary. It should, of course, be realized that most of the deformities treated by these methods were severe and that, frequently, adaptive bone changes had already occurred.

This series reveals the effectiveness of the soft-tissue procedures in achieving eventual permanent correction of the club-foot deformity or, at least, in controlling the deformity until such time as a definitive bone operation can be performed. Of the 136 soft-tissue operations, only fourteen were supplemented by tarsal arthrodesis. It must be added, however, that eventually two additional patients will require bilateral arthrodeses (Figs. 10-A and 10-B), and one other may require arthrodesis of the right foot to control a recurring deformity (Figs. 11-A through 11-D). In one patient tarsal arthrodesis, performed at the age of five and one-half years, was followed by recurrence of the deformity, but when the operation was repeated two years later, the result was reasonably good. Functionally and cosmetically, the best results were obtained in those patients in whom tarsal arthrodesis was delayed until the bone structure of the foot was relatively mature. Derotation osteotomy of the tibia should be done only when medial tibial torsion remains as the single uncorrected element of the presenting congenital deformity. It should probably not be done early because of the possibility of spontaneous correction.

NOTE: The authors wish to acknowledge the assistance of the following men in the preparation of the illustrations: W. A. Stultz, Associate Professor of Anatomy; V. H. Paquet, Assistant Professor of Mechanical Engineering; L. Damon, Graduate Assistant in Mechanical Engineering; and F. C. Mallory, Director of Medical Photography.

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DISCUSSION

Dr. David S. Grice, Boston, Massachusetts: This report by Dr. Bell and Dr. Kuhlmann reminds us that the treatment of club-foot is not always successful and that it may on occasion be very difficult. These authors are not radical surgeons who hastily operate on every club foot. They are conservative Vermont men who well appreciate the need for starting treatment early and for maintaining the correction by means of night supports and exercises. They have stated that the majority of patients do not require surgery.

The cases presented are those of patients in whom adequate correction could not be obtained by conservative means or in whom the deformity persistently recurred. The authors have recognized that in some patients the posterior elements are so tight that correction can be obtained only by forcible wedging, which produces deformity of the mid-tarsal bones, or by surgical lengthening. They have shown that the latter is often preferable. They have also recognized the problem of muscle imbalance and in their patients have transplanted the tibialis anterior in order to restore the normal balance after the deformity has been corrected.

I would like to point out that following lateral transplantation of the tibialis anterior to the fourth or fifth metatarsal, it is often necessary to secondarily transplant the tendon to the mid-foot. The strength of the toe extensors and the peroneals should be carefully evaluated, and if they are strong, the tibialis anterior need not be moved farther laterally than the second or third metatarsal.

Dr. J. H. Kite, Atlanta, Georgia: Of the six major procedures used in the authors' series of fifty-three patients, three were done only four, six, and eight times, respectively. I must apologize for repeating what has already been said many times before—namely, that a report which is based on so few cases has no real statistical value. One of the procedures used most frequently was the Ober ligamentous release, which was done on sixteen feet. In only 31 per cent of these feet were good results obtained, and in the other 70 per cent additional operations either have been or will be done. I think the only way we can evaluate a surgical procedure is to know more about it. We would like to know about the selection of cases, whether the procedure was done at the right age, and, above all, whether it was done correctly according to the method outlined by the author. We would also like to know whether it was done by one doctor or by sixteen doctors, and whether it was done by a senior surgeon or by a junior surgeon. It would also be important to know about the follow-up treatment.

The patient shown in Figures 11-A to 11-D was treated by bilateral tendo achillis lengthening and posterior capsulotomy. Later, medial release of the soft parts and lateral transplantation of the tibialis anterior tendon were done. The authors have stated that the heel was still in a slightly varus position and that tarsal arthrodesis would probably be necessary. On the basis of results such as this, I wonder whether operations are really valuable or whether they are on the whole disappointing.

In their evaluation of the operative treatment of club-foot, I had hoped that the authors would be able to recommend one procedure that they considered of real value. It seems that the procedure that was most satisfactory was the insertion of a Kirschner wire in the tibia, calcaneus, and metatarsals, combined with the use of three horseshoes connected by a series of six threaded rods. The authors illustrated the use of this procedure in a two-year-old boy. The apparatus was adjusted once a week with the patient under anaesthesia. In addition to this treatment, tendo achillis lengthening and posterior capsulotomy were done. When the patient was three, lateral transplantation of the tibialis anterior was also done. The authors showed a photograph of the patient at four to illustrate the value of the method, but I wonder if the final result can be determined so early.

In five cases in which transplantation of the tibialis anterior was done, it was necessary to retransplant the tendon, bringing it back nearer to the mid-line. The authors mentioned one patient treated by astragalectomy in whom, at eighteen years of age, it was necessary to fuse the ankle because of pain.

In the last case presented by the authors to illustrate the value of tarsal arthrodesis, the patient was operated upon when he was five and one-half years old. When he was seven, the operation had to be repeated, and when he was twelve, the roentgenograms showed absorption of the talus into the calcaneus and butting of the navicular against the anterior margin of the tibia. The authors have said that the foot was relatively satisfactory for weight-bearing but that there was still some residual varus deformity of the heel.

If operative treatment of club-foot, done at an early age, would give results as excellent as those obtained by operative treatment of other deformities, I would certainly support this approach. I have operated on over a hundred club feet, most of which had already been treated at other clinics, and have found that triple arthrodesis, done at a late age, probably gives the best results.

Hippocrates may well have been referring to the treatment of club-foot when he said that that which we can do without force, we probably can do without harm. Perhaps even in his day club feet were being harmed by forcible correction. In closing, I would like to leave this suggestion: of the eighty-two club feet in the authors' series, seventy-eight were operated upon—it might be that if the authors would make a careful study of the four feet which were treated without operation, they would find the secret of the correction of club-foot. It is my guess that twenty years from now these four feet will be the best four in the series.

Dr. Carl J. Roncaglione, Richmond, Virginia: The exhibit of Dr. William Deyerle and myself on the treatment of club-foot is a manifestation of the increased interest in this problem in the Department of Orthopaedic Surgery at the Medical College of Virginia at Richmond. We felt that a brief discussion of our experiences would be appropriate at this time.

The authors from Vermont have reviewed a number of operative procedures employed in the treatment of resistant and recurrent club-foot. We further mention blind subcutaneous tenotomy, capsulotomy, and fasciotomy only to point out that we have discarded these procedures completely. We feel that the number of patients requiring any kind of surgery can be kept to a minimum by the enthusiastic application of the principles of plaster treatment outlined by Dr. J. H. Kite.

In our series of patients treated by the application of plaster casts under the direction of a single attending physician, we found it necessary to operate on only three of forty-eight feet. Two of these operations consisted in tendo achillis lengthening and posterior capsulotomy, and we now believe that these operations could have been avoided had the plaster-cast treatment not been interrupted against advice.

In our control series (which we call "control" primarily because we had no control over the treatment used), eighteen patients with twenty-nine club-foot deformities underwent thirty-two operations. A comparison of the results in these two series shows that the total length of time in casts was reduced from 29.6 months in the control group to 4.9 months in the group treated by plaster casts and that the duration of hospitalization was reduced from 5.6 months to 0.6 month. Furthermore, the number of unsatisfactory results requiring bone surgery was reduced from 22 per cent to 3.3 per cent. This is ample evidence, we believe, that surgery is necessary in only a very few patients provided enthusiasm and persistence in the application of plaster casts is sufficient and provided casts are reapplied at the earliest sign of recurrence. In our experience we have been able to clearly establish the need for surgery only by continuing this conservative regimen for a period of twelve to eighteen months or longer.

Our worst results occurred in the patients who had previously undergone blind subcutaneous surgery. Of the twenty-nine patients in this group, twenty-six required additional operative procedures and six subsequently required radical medial release. Of the forty-eight feet treated by the application of plaster casts, only one required radical medial release, the only alternative in this case being to wait five to seven years until bone surgery could be done.

When, after repeated failure of conservative management, radical medial release is clearly indicated, we believe the foot should be opened and explored and the deforming structures visualized and released. In the seven cases in our two series in which this operation was necessary, our usual procedure was as follows.

An L-shaped incision was made over the tibialis posterior tendon, and the neurovascular bundle was retracted. The lacinate ligament was then explored, and if it was found to be thickened and leathery, it was excised. Next, the tibialis posterior tendon was explored. In all of our cases, we found it to be enlarged and to have anomalous attachments to the lacinate ligament, the talus, and the calcaneus. These attachments were excised. In three of the seven feet, we found an anomalous muscle located close to the posterior aspect of the tibialis posterior tendon. The tendon of this anomalous muscle inserted into the plantar fascia in much the same fashion as does the tendon of the palmaris longus of the hand. In another foot, we found an abnormal condition which had been created by previous surgery.

In every case we found the deltoid ligament, the talonavicular capsule, and the subtalar-joint capsule thickened and fibrotic and contributing materially to the deformity. These were excised sufficiently to allow

(Continued on page 420)

The Dowel Intervertebral-Body Fusion as Used in Lumbar-Disc Surgery*

BY B. R. WILTBERGER, M.D., COLUMBUS, OHIO

From the Department of Surgery, Division of Orthopaedic Surgery, The College of Medicine, Ohio State University, Columbus

Many orthopaedic surgeons who find merit in the intervertebral-body fusion are reluctant to use this method of arthrodesis because existing techniques make the operation seem too difficult and too dangerous. During the past four years an attempt has been made to perfect a simplified method of vertebral body-to-body fusion which would make the procedure more practicable and less hazardous. The operation is a dowel intervertebral-body fusion in which standard-sized drill holes are prepared between the vertebral bodies across the intervertebral-disc space. Slightly oversize, standard pre-cut dowels of autogenous or homogenous bone [1] are inserted in the holes (Fig. 1). This procedure has been performed in a series of sixty-eight patients.

It is not suggested that the dowel fusion be considered an integral part of routine disc surgery, but rather a method of fusion to be used in conjunction with disc surgery. Since the report of Mixter and Barr in 1934, in which the herniated disc was first established as a distinct clinical entity and in which operative treatment of the herniation was described, many articles [6, 8, 12, 13] have been published discussing the indications, virtues, and disadvantages of spine fusion following laminectomy.

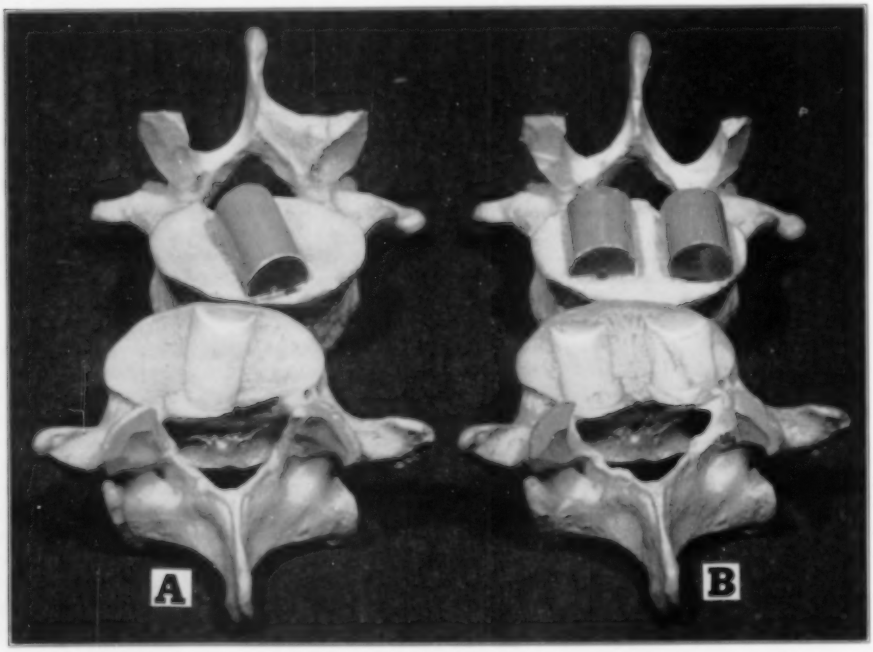

FIG. 1

A, single dowel, diagonally placed; *B*, double dowel.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, February 2, 1956.

The posterior interbody fusion following lumbar-disc removal was first reported by Jaslow in 1946; it has since been employed by an increasing number of surgeons with favorable results. Cloward of Hawaii has been using the body-to-body fusion technique in conjunction with disc surgery for approximately ten years. James and Nisbet of New Zealand use the intervertebral fusion in patients with spondylolisthesis, as well as in those with prolapsed discs.

However, it is interesting to note that Adkins of Derby, England, has concluded that "intercorporal bone grafting, although it appears to aid in the formation of a firm fibrous ankylosis, is ineffective as a method of producing bony arthrodesis."

An appraisal of the dowel intervertebral-body fusion indicates that it offers the following technical advantages:

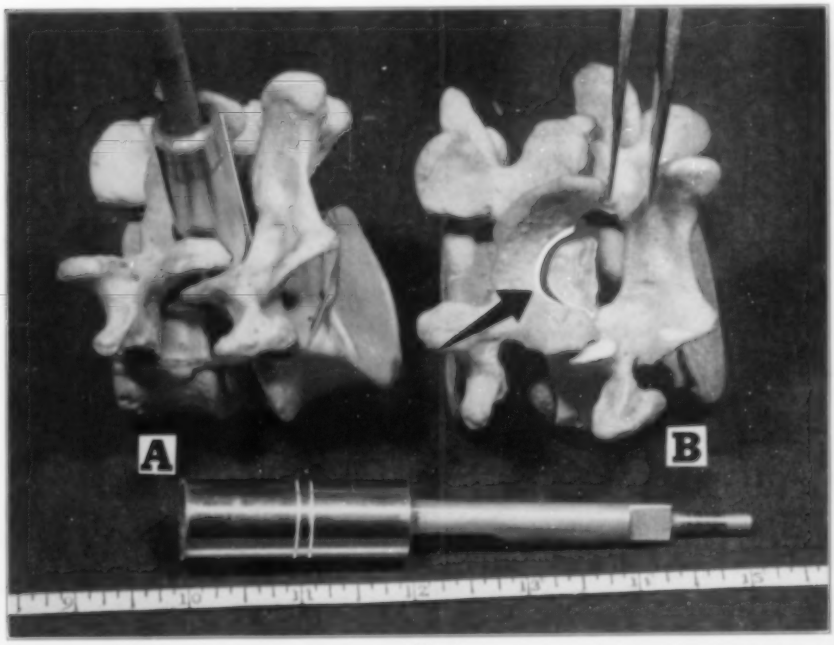

FIG. 2

A, Iliff trephine is used to cut a semilunar portion from the lamina; *B*, the semilunar hole has been cut in the lamina and a piece of bone has been removed (arrow).

1. Such a graft physiologically fulfills the requirements of osteogenesis; the graft is under compression and it is in perfect contact with the recipient site.

2. The procedure is atraumatic. Approximately one-half hour for each level fused is added to the operating time required for a laminectomy. In many instances, transfusion is not necessary, but two units of blood are reserved in the operating room to be used if needed.

3. The dowel acts as a plug, aiding hemostasis, and prevents the extrusion of any remaining degenerated disc material.

4. Injuries to the large anterior vascular structures are avoided by the use of especially designed instruments.

5. This procedure is a distraction fusion.

6. The dowel fusion is precision grafting, standardized parts being used. Since no fitting is required, very little donor bone is needed.

7. Should further surgery be necessary, it is possible to re-enter the area without

having to remove a graft; and, since so little bone was removed in the original procedure, it will still be possible to do a posterior spine fusion.

8. This method of fusion can be used when previous surgery has destroyed the posterior elements and made posterior fusion impossible or possible only with great technical difficulty.

The dowel intervertebral fusion does have the following disadvantages:

1. It is precision grafting and great care must be taken to position the graft correctly.

2. The risk of injury to the dura and to the nerve roots is greater with this type of bone graft.

3. If the wound becomes infected, it is possible that the vertebral bodies will be involved.

4. Posterior extrusion of the graft is possible.

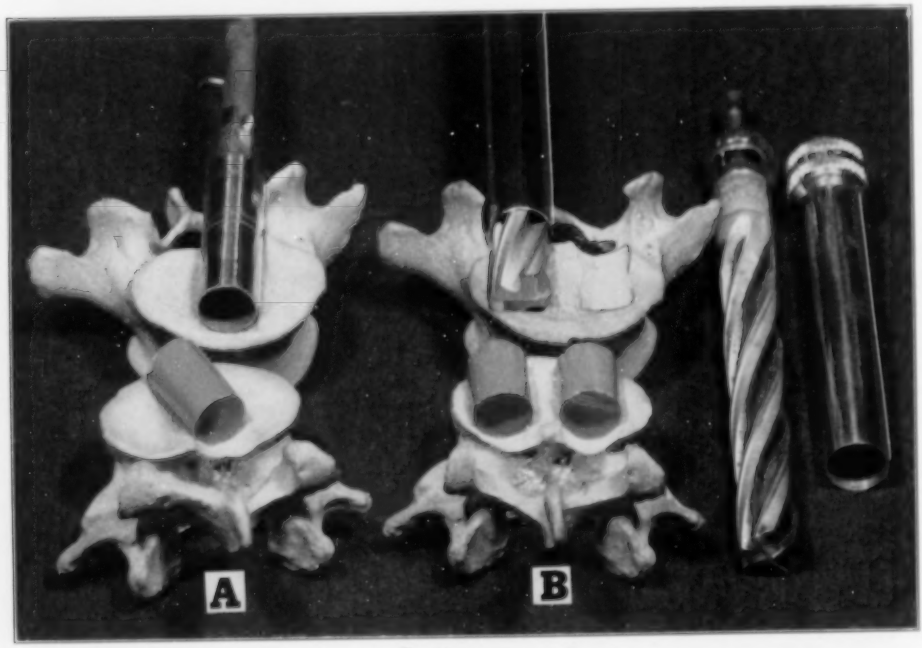

FIG. 3

A, an Iliff trephine is used to cut a cylindrical hole in vertebral bodies; *B*, a cylindrical hole is cut in the vertebral bodies by means of a five-eighths of an inch drill with a protective depth-gauge sleeve.

OPERATIVE TECHNIQUE

The disc is resected as indicated. A unilateral partial laminectomy is performed or, if the patient has symptoms bilaterally, a bilateral procedure is done. The degenerated nucleus pulposus is removed as completely as possible.

The vertebral bodies are distracted by cutting away the interspinous ligament and by placing a lamina spreader between the contiguous spinous processes. The dura and the nerve root are retracted medially, a broad nerve-root retractor being used in order to protect them. A cottonoid square attached to No. 2 braided silk is packed laterally and slightly cephalad in the vertebral interspace in order to protect the nerve root exiting one space above. By means of a five-eighths of an inch outside diameter Iliff trephine on an oscillating saw, a small semilunar portion of the lamina of the cephalad vertebra is removed. This creates a circular opening five-eighths of an inch in diameter between the laminae directly over the disc space (Fig. 2). Care is taken, consistent with adequate

exploration, to preserve the facet. If the Iliff trephine is marked to indicate depths of one inch and one and one-eighth inches, it can be used to cut the cylindrical hole between the vertebral bodies (Fig. 3, *A*); the surgeon can readily observe the penetration of the trephine and can stop at the predetermined depth. The cylindrical hole can also be cut by means of a five-eighths of an inch drill with a protective depth-gauge sleeve (Fig. 3, *B*). If one dowel is to be used, the cylindrical hole should be cut diagonally between the vertebral bodies (Fig. 1, *A*). If a double dowel is to be used, the openings should be cut directly posteriorly-anteriorly from a bilateral partial laminectomy (Fig. 1, *B*). It is imperative that both vertebral end plates be removed during this cutting process in order to expose the vertebral cancellous bone.

If iliac dowels are to be used, they can be procured from the posterior-superior iliac spine through a small incision (Fig. 4). The eleven-sixteenths of an inch Collet chuck-type

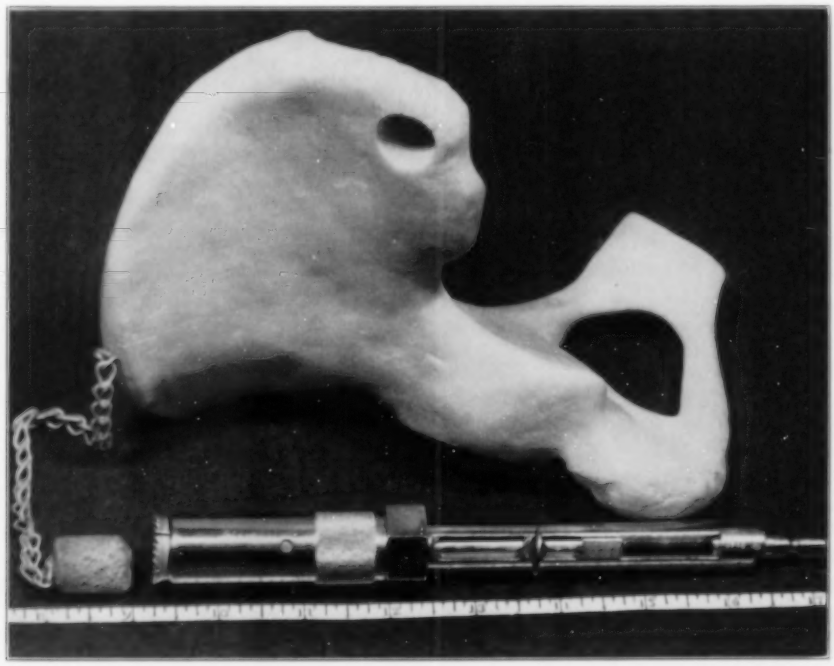

FIG. 4

Iliac dowel removed from posterior-superior iliac spine by a Collet chuck-type hole saw.

hole saw is used. From this area it is possible to obtain several dowels, three-fourths of an inch to one inch in length.

The surgeon who prefers tibial grafts may cut a strip, three-fourths of an inch wide, from the anterior-medial surface of the middle and proximal thirds of the tibia. The tibial strip is then cut into lengths, seven-eighths of an inch long. Two lengths are placed cortex to cortex and, by means of the eleven-sixteenths of an inch inside diameter Iliff trephine, they are cut to form one dowel seven-eighths of an inch long and eleven-sixteenths of an inch in diameter (Fig. 5).

While the vertebrae are temporarily distracted to a maximum degree, the dowels, either iliac or cortical, are driven into place and countersunk one-fourth of an inch with a bone set.

Postoperatively, the patient remains in bed for three weeks, but is allowed to move freely using the "log-rolling" technique to change position. After the initial three weeks,

he gradually becomes ambulatory. A chair-back brace is worn when he is up and about. Most patients wear the chair-back brace for about eight months after the operation. After this period of convalescence the patient slowly returns to normal activity.

RESULTS

Over a two-year period, vertebral body-to-body fusions were performed on fifty-two patients, all of whom have been followed for at least two years. Forty-six (89 per cent) of these patients were available for frequent follow-up examinations, and an attempt was made to assess the end results by clinical observation and by a study of mobility roentgenograms, which, admittedly, are difficult to interpret. The group of forty-six patients included ten who had had fusion at two levels, making a total of fifty-six interspaces operated upon.

FIG. 5

A cortical dowel is made from two strips of tibial bone, an Iliff trephine being used.

Roentgenographic studies of the forty-six patients showed non-union in six (13 per cent). Of the fifty-six fusions which were performed on the forty-six patients, non-union resulted in 11.5 per cent.

A study was made of the ten patients who required spine fusion at two levels, from the fourth lumbar vertebra to the fifth and the fifth lumbar vertebra to the first sacral vertebra. Two non-unions (20 per cent) were found, one at each level. When only one vertebral interspace was involved, 11 per cent resulted in non-union.

However, when the one vertebral interspace fused was the lumbosacral joint, only 6.1 per cent of the fusions failed. (There were two non-unions in thirty-three fusions.) These findings were consistent with those reported by Bosworth, whose study indicated that the percentage of non-unions increased from 3.5 per cent when the lumbosacral joint only was fused, to 17.3 per cent when two levels were fused—the fourth lumbar vertebral joint to the fifth, and the fifth lumbar vertebral joint to the first sacral.

One operation was performed above the fourth lumbar vertebral level. This was at the third lumbar level and postoperative examination proved fusion to be solid.

Of the forty-six fusions studied, twenty-six were bilateral dowel fusions and twenty were single dowel fusions. There were two non-unions (7.7 per cent) among the twenty-six bilateral dowel fusions; there were four non-unions (20 per cent) among the twenty single dowel fusions.

There were three non-unions in ten cortical tibial grafts and three non-unions in

TABLE I

RESULTS

	Number	Per cent
Very good	32	70
Improved	8	17
Not Improved	6	13
Total	46	100

thirty-six iliac grafts. Postoperative roentgenograms of the three cortical grafts which resulted in non-union showed, in two instances, that the graft was not in contact with cancellous bone in both vertebrae. Improperly placed tibial grafts accounted for one-third of the total non-unions of the cortical grafts.

After following the series of forty-six cases clinically and roentgenographically for more than two years, it was concluded that results in 70 per cent could be classified *good*. These patients were completely asymptomatic or had only occasional slight leg pain or cramps which required no treatment; there was no restriction of normal activity. Seventeen per cent of the series were much improved and these results could be considered *satisfactory*, although the patients had moderate back or leg pain sufficient to prevent them from participating in athletics or performing work requiring heavy lifting. These patients, although restricted in their activities, were able to work. Thus, results of 87 per cent of this series can be classified *satisfactory*. Results in the remaining 13 per cent were *not satisfactory*, for these patients continued to have back or leg pain severe enough to prevent them from earning a living.

Of sixty-eight patients operated upon, two had deep wound infections (2.9 per cent). Although both infections responded to antibiotics and to drainage, it was necessary in

FIG. 6-A
Typical fusion.

FIG. 6-B
Typical fusion.

one patient to remove one side of a bilateral cortical graft. There was extrusion of the graft posteriorly in two patients; surgical procedures were necessary to replace the graft in one patient and to cut off the protruding graft in the other. However, in the final analysis, the results of both cases were classified *satisfactory*.

Neurological complications, such as postoperative numbness, burning pain, and slight motor weakness, occurred frequently in the patients in whom the dowel fusion was performed. These symptoms subsided in about a week. The incidence of nerve-root trauma was reduced by placing the patient in an inverted Fowler's position on the operating table with the hips and knees flexed in order to relax the nerve roots, and by handling the nerve roots carefully during the surgery. There was one case (1.5 per cent) of permanent foot-drop.

Over a four-year period, the author has performed the dowel intervertebral-body fusion on sixty-eight patients. No deaths have occurred. There was no indication of injury to the major blood vessels anterior to the lumbar spine in any of the patients.

Of the forty-six patients, 89 per cent returned to employment. Seventy per cent were able to return to their former jobs or to a comparable occupation. Forty-eight per cent of the group received industrial or railroad compensation.

DISCUSSION

The statistics reported may give an erroneous impression regarding cortical grafts as most of these operations were done during the last two years of the four-year period. Since these patients have been observed for only two years, they are not included in this study. The author believes that time will prove that the tibial cortical graft has more structural stability than the iliac graft. Although the statistics show that there are fewer non-unions when iliac bone is used, an appraisal of unsatisfactory results seems to indicate that a gradual telescoping of the iliac graft often takes place. For this reason it seems advisable to insert bilateral dowel grafts when iliac bone is used.

CONCLUSIONS

1. The dowel intervertebral-body fusion is a simplified, safe way of doing body-to-body fusion.

2. The dowel fusion is an atraumatic form of interbody fusion and can be done in relatively short operative time.

3. As in other methods of fusing of the spine, the results of the dowel fusion appear to be the most successful when fusion is done between the fifth lumbar vertebra and the sacrum. It is less successful when two levels are grafted.

4. It is advisable, when using iliac bone, to insert bilateral dowel grafts. The series in which cortical grafts were used is too small for evaluation.

5. To assure bone union, it is necessary to remove the vertebral-body end plates in the area of the graft in order that the dowel will be in contact with the cancellous bone of the vertebral bodies above and below the graft.

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DISCUSSION

Dr. Robert J. Joplin, Boston, Massachusetts: Dr. Wiltberger is one of the pioneers in the field of intervertebral-body fusion without posterior fusion. The subject is not entirely new to me, for I visited Dr. Wiltberger over two years ago and saw several of his convalescent patients. Some of these patients demonstrated the complications which he lists as possible disadvantages of the procedure. At that time I had the impression that this operation was a formidable procedure which had a dangerously high incidence of nerve-root damage. Last month, when I visited his clinic again, I learned that most of the complications I had seen were transient; that 89 per cent of the patients were working and that 70 per cent had returned to their former occupations. Dr. Wiltberger had not performed many dowel fusions up to two years ago; consequently, his follow-up report includes only ten cortical grafts and thirty-six iliac grafts. Therefore, I question whether conclusions concerning the relative merits of the two types of grafts are logical. However, if we wish to evaluate the results of intervertebral-body fusion alone, I know of no series of cases better and more carefully analyzed.

If we wish to compare any body fusion with posterior fusion, we find that when any body fusion was performed at the two levels, fourth lumbar to first sacral, there was 20 per cent non-union. This figure was reduced to 6.1 per cent when only the fifth lumbar and the first sacral vertebrae were fused. Although the series is small, the percentage of non-union is greater than that in the series of posterior-graft fusions reported by Bosworth (17.3 per cent for fusions of fourth lumbar to first sacral vertebra and 3.5 per cent for fusions of fifth lumbar to first sacral vertebra). Therefore, the percentages given in this report lead one to suppose that interbody fusion alone is no better than posterior fusion.

In a comparison of bilateral dowel fusions with single dowel fusions, it was revealed that there was only 7.5 per cent (two patients) non-union among the twenty-six bilateral fusions and 20 per cent (four patients) among the single fusions. This may be considered a comparable series which, according to these results, suggests that the more bone inserted, the better the chance of fusion.

It is of interest in this connection that in the cases reported by Adkins, who used small fragments of bone for interbody fusion, there was an exceedingly high percentage of non-union. It would seem, therefore, that success of interbody fusion depends on enough bone being used to prevent a rocking motion and to provide complete stability during the postoperative healing stage.

The author states that an appraisal of the unsatisfactory results of the procedure indicates a gradual telescoping of iliac grafts. As a matter of fact, both cortical-bone grafts (from the tibia) and cancellous-bone grafts settled, but the cancellous-bone grafts settled more. Since all the unsatisfactory results were among patients in whom cancellous-bone grafts were used, he assumes that settling or "telescoping" is, in some way, associated with the cancellous grafts—but this is not proved.

Since the question of fusion following disc removal is still before us, it is pertinent to comment that Barr, in 1947, observed from end-result studies that "at least 50 per cent of the patients who have had ruptured discs removed without spine fusion suffer to some degree from weakness and back pain. Assuming that a technique of fusion can be developed which will not cause undue increase of operative risk or prolonged postoperative convalescence, it appears logical that fusion should be done in practically all cases."

If Dr. Wiltberger obtained 87 per cent satisfactory results with interbody grafts, and others obtained satisfactory results with posterior grafts, and assuming that there is need for improvement of the procedure, would not a combination of procedures give us better results than either method used alone? From various

reports, we know that there are surgeons who are doing such combined procedures. The beginner should be warned, however, that much experience should precede such a combined operation.

Dr. I. S. McReynolds, Houston, Texas: Dr. Wiltberger's interesting paper presents a controversial operative procedure.

My first experience with interbody fusion was in 1953, when Dr. Cloward demonstrated his operative method on a patient of mine. Also, that same year I first used plug cutters on an oscillating saw to remove the intervertebral disc and to prepare an iliac graft in a manner similar to the technique described by Dr. Wiltberger. All the operations I have done have been bilateral grafts which has definitely prolonged the operative procedure. After doing ten or eleven interbody fusions, I feel that the operation has not been successful in obtaining either a solid bone fusion or a satisfactory relief of symptoms in a high enough percentage of patients.

This particular type of operation requires great technical skill because it is a precision operation. Major complications as a result of the operation are possible. This procedure is not to be classed as a simple operation and cannot be carried out in a short period of time in all instances, nor can it be carried out by all qualified orthopaedic surgeons.

Although my experience with the operation has been limited, it has been sufficient to convince me of its shortcomings. Interbody fusion cannot be regarded other than as a major operative procedure. There are fewer technical difficulties in operative exposure in cases of spondylolysis or spondylolisthesis, in which the entire posterior element is excised. I feel that to supplement an interbody fusion with a graft over the posterior element is an admission of the inadequacy of interbody fusion.

I am sure that Dr. Wiltberger's experience and ingenuity has enabled him to carry out this operation more efficiently, perhaps, than anyone else. I am impressed with Dr. Wiltberger's enthusiasm and his efforts to work out this problem, and I accept Dr. Wiltberger's report of 87 per cent satisfactory results—a percentage far higher than mine. I believe, however, that it is difficult to obtain a solid fusion of the vertebral interspace; and certainly, solid fusion cannot be obtained in a short time, or Dr. Wiltberger's patients would not require a back brace to be worn for as long as eight months after surgery. My own low incidence of proved fusion, and Adkins' failure to demonstrate evidence of incorporation of the graft in all but possibly one of his seventy cases are a strong contrast with Dr. Wiltberger's results of 13 per cent non-union.

I question whether Dr. Wiltberger has had as many solid fusions as he sincerely thinks he has. My reason for questioning his successful fusions is because most of the operations were performed at the fourth and fifth lumbar interspaces, and the only roentgenographic projection capable of accurately determining whether or not the graft is incorporated with the vertebral bodies is the tilted-tube anteroposterior projection with the central ray directly in the anteroposterior axis of the interspace. If absorption of the dowel is present, it can be demonstrated only by this projection. If the central ray is not centered through the anteroposterior axis of the interspace, overlapping bone shadows may create a false impression of fusion. From my studies of the procedure, I am forced to the opinion that Dr. Wiltberger's technique does not solve all problems of the diseased disc. Even with Dr. Wiltberger's refinement in technique, the operation is still too difficult to be universally accepted and I urge that the procedure be approached with caution.

Dr. Duncan C. McKeever, Houston, Texas: I have done vertebral interbody fusions with hand tools since 1947, and with the Stryker plug-cutting trephines for the past two and one-half years. I have done this procedure only when removal of the intervertebral disc was necessary, and it has always been combined with an intrinsic internal-fixation type of posterior fusion. Vertebral interbody fusion should not be a routine procedure.

The problem of spine fusion is basically a mechanical one. When we attempt internal fixation in any orthopaedic problem, fusion must occur or continued cyclic stress will result in failure of the internal fixation.

In the spine, internal fixation should immobilize the segments in the anteroposterior plane and in the transverse plane. To do this, resistance to motion must be afforded in both arcs in each plane. Interbody fusion, so obviously desirable, must be considered feasible or we must postulate that no spine fracture can heal. This, of course, is not the case, and, therefore, interbody fusion must be possible. Disease processes produce such fusions. How can surgery produce the same?

We can do this by maintaining optimum compression stress between the bodies of the vertebrae transmitted through a suitable graft material in direct contact with the cancellous portion of the adjacent bodies. To secure this bone contact, an area of the subchondral plate must be removed on each body. Dr. Wiltberger is offering a method by which this can be accomplished. The fact that failure has occurred in some cases is because of lack of sufficient adjunct intrinsic internal fixation to allow the consolidation.

It is possible that the addition of the interbody element in spine fusion is not necessary when the disc is intact except in cases of extreme hypermobility and spondylolisthesis. If the disc is not intact, one element of stability has been lost and intercorporal fusion will restore this stability. This should be done if it is surgically feasible.

(Continued on page 331)

Slipped Femoral Epiphysis with Severe Displacement

A Conservative Operative Treatment*

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The treatment of slipped femoral epiphysis which is discussed in this article is confined to the advanced stages of progressive slipping in which there is consolidation with severe displacement and severely disabling limitation of motion. Open reduction through the epiphyseal plate or cuneiform osteotomy through the neck of the femur are commonly considered necessary in these severe displacements for correction of the deformity and restoration of motion. While some surgeons report good results from the use of one or the other of these procedures, many others have had poor results because of aseptic necrosis and choose, instead, subtrochanteric osteotomy in order to obtain functional abduction and internal rotation.

Another, more conservative, operative treatment is proposed to those who may be dissatisfied with these procedures. This treatment, osteoplasty, is recommended after fourteen years' experience in its use and follow-up observations of patients treated by the method. Although anatomical reduction of a slipped epiphysis is desirable, it is not necessary for the restoration of good function. Traumatic arthritis or osteo-arthritis may eventually develop because of malposition, but this is unlikely to occur before middle age. It is preferable, therefore, that an adolescent patient should be comparatively symptom-free during the intervening years, rather than to subject him to a risk of immediate and permanent disability so early in life in order to obtain reduction. Should osteo-arthritis occur during later years, it can be dealt with then, and in the meanwhile the patient can have many years of comfort and practically normal activities.

The first of these osteoplastic operations was done in 1935, resulting in an excellent restoration of motion and relief of symptoms. However, the patient's postoperative progress was not followed longer than one year because his family moved to another state and could not be traced. In 1942, another osteoplastic operation was done. The patient was a boy, fifteen years old, who had a severe displacement of the hip with symptoms of five months' duration. The hip was painful, there was limitation of flexion and complete loss of abduction and internal rotation. On examination, cervical osteotomy or open reduction with insertion of a nail for fixation seemed to be the only satisfactory method of treatment. Preparations were made for this and an incision was made accordingly. Even when the patient was under anaesthesia, little motion at the hip was possible, and there was found to be a severe downward and backward displacement of the femoral epiphysis with solid union in this position. The obstruction to motion was identified as a large bony prominence at the anterosuperior aspect of the neck of the femur at its junction with the displaced epiphysis, which was seen to impinge against the rim of the acetabulum. Instead of performing an osteotomy, this bony prominence was removed with an osteotome. The patient's hip could then be moved freely in all ranges, except for some limitation of abduction. Postoperatively, no protection was used. Active exercises were prescribed at once, and the boy was up with crutches and bearing weight on the extremity within one week. He was soon bearing full weight on the limb and he retained most of the restored range of motion. Fourteen years later he continued to have no complaint or limitation of activities. He had no limp, 90 degrees of flexion,

* Read at the Annual Meeting of The American Orthopaedic Association, Banff, Alberta, Canada, June 23, 1956.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Roentgenogram made November 4, 1942, of R. C., a boy fifteen years old, who had had severe displacement of the hip with symptoms for five months. There was little motion of the hip even under anaesthesia. Note the angular prominence of bone at the neck of the femur adjacent to the rim of the acetabulum. This was removed by osteoplasty on November 17, 1942, without attempting to reduce the displacement. A good range of motion was obtained immediately.

Fig. 1-B: Roentgenogram made December 10, 1943. Most of the angular bony prominence has been removed. The patient had no pain and had good motion at the hip.

FIG. 1-C

FIG. 1-D

Figs. 1-C and 1-D: R. C. Roentgenograms made January 4, 1952, ten years after operation. Although a small ridge of bone was still present at the upper surface of the femoral neck, the patient had good range of motion in all directions. There are small cyst-like changes at the distal portion of the femoral neck but the articular surface is smooth and the joint appears normal. In 1956, fourteen years after treatment, the patient had no limp, 90 degrees flexion, good abduction, and internal rotation beyond the neutral position.

internal rotation to the neutral position, and good abduction (Figs. 1-A, 1-B, 1-C, and 1-D).

In 1947, the osteoplastic procedure was used in a patient with long-standing bilateral slipped femoral epiphyses with displacement of the epiphysis and limitation of motion in both hips. The condition had existed for two years in the left hip and for one year in the right hip. The patient had great difficulty in walking and sitting because of stiffness and pain. Both lower extremities were in severe external rotation; there was only 20 degrees of flexion and there was loss of abduction and internal rotation. Here one could operate upon one hip only and use the other hip as a control.

Before proceeding with surgery, however, it was thought desirable to determine the effect of traction and bed rest. After four weeks of thirty pounds of skeletal traction through the distal portion of the left femur, there was no improvement in the range of motion in either hip and no change was seen in the roentgenograms. Osteoplasty was then performed upon the left hip. An almost complete range of motion was obtained by removing the bony prominence which had impinged against the rim of the acetabulum. Postoperative early motion, exercises, and weight-bearing were prescribed. Before operating upon the right hip, the patient was sent home with crutches to see if the restored good motion in the left hip would be retained.

She returned to the hospital five months later for the operation upon the right hip. There had been no improvement in the right hip in the meanwhile, but there was an excellent range of motion in the left hip. Osteoplasty was done in the right hip, resulting in prompt restoration of good motion and relief of symptoms. When seen nine years later, the patient had no limp, no disability, and no complaint. Motion in both hips was normal except for slight limitation of internal rotation of the right hip (Figs. 2-A, 2-B, 2-C, and 2-D).

As the femoral epiphysis becomes displaced downward and backward, and the neck of the femur rides upward and forward in relation to the epiphysis, the proximal portion of the femoral neck appears as an angular or rounded ridge of bone at the anterosuperior aspect. In severe displacement, this bony prominence presses against the rim of the acetabulum, obstructing abduction and internal rotation. Flexion is possible only with the extremity in external rotation. In severe displacements, flexion may also be greatly limited. The resulting disability is limp, limitation of motion, and deformity of the hip with the extremity in external rotation and adduction. The amount of shortening present in the limb depends upon the amount of upward riding of the neck of the femur. Adduction and extension are rarely limited unless there are secondary degenerative articular changes. The direction in which the bony prominence faces, whether predominately anteriorly, superiorly, or anterosuperiorly, determines the planes or arcs of motion most affected.

The osteoplastic operation consists in removing this angular or rounded prominence of bone at the neck of the femur where it adjoins the femoral head. The Smith-Petersen approach provides a good exposure. The joint capsule is incised longitudinally at the anterosuperior aspect of the neck of the femur and transversely at the rim of the acetabulum. The articular cartilage covering the head may not be readily identified because the epiphysis may be rotated far backward and downward. By adducting the hip and rotating it externally, the margin of the articular cartilage may be brought into view. This exposure is important because the articular cartilage should not be damaged. It is not important to try to identify the epiphyseal line. The hip is then moved through all

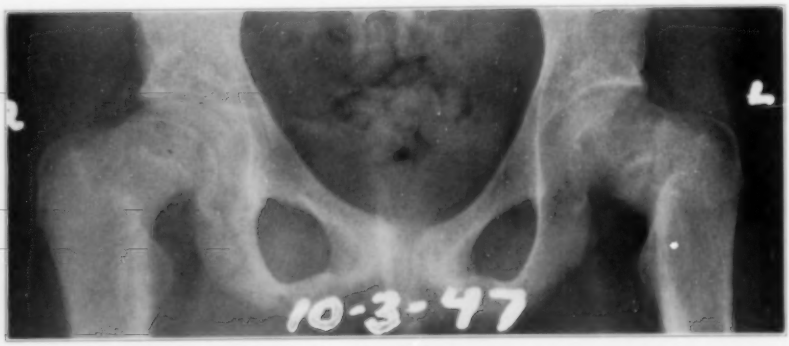

FIG. 2-A

Roentgenogram made October 3, 1947, of R. D., a girl fourteen years old. The patient had had complete disability of the left hip for two years and of the right hip for one year. Osteoplastic procedure at the neck of the left femur was done on November 12, 1947, and at the neck of the right femur on May 26, 1948, with no attempt to reduce the severely displaced femoral epiphyses.

FIG. 2-B

R. D. Roentgenogram made April 2, 1954, six years after the operation. The patient had no limp and no appreciable limitation of motion at either hip.

FIG. 2-C

FIG. 2-D

Figs. 2-C and 2-D: R. D. Roentgenograms made April 2, 1954, six years after the osteoplasty. Note the good joint space, the smooth articular surface, and the normal trabeculation of the head and the neck of both femora.

FIG. 3-A

FIG. 3-B

Fig. 3-A: Roentgenogram made December 1, 1955, of M. C., a girl thirteen years old, who had had severe displacement of the femoral epiphysis with pain and limp for six months. The epiphysis was seen to be practically fused with the neck of the femur. The hip was in severe external rotation and it could not be rotated internally. Abduction was limited. Flexion in the externally rotated position was limited to 60 degrees.

Fig. 3-B: M. C. Roentgenogram made February 3, 1956, seven weeks after the osteoplastic procedure performed on December 4, 1955. A sufficient amount of bone was removed to permit free motion at the hip. The patient was in bed for one week after the operation, and was then encouraged in unrestricted activity. No attempt was made to reduce the displacement of the epiphysis. On May 4, 1956, there was a slight limp but flexion and extension were normal, internal rotation was well beyond the neutral position, and there was a moderate limitation of abduction.

its ranges of motion, noting where the bony ridge or prominence impinges against the rim of the acetabulum. The periosteum is incised in the long axis of the femoral neck and, transversely, a short distance at each end of this incision. The periosteum is not raised more than is sufficient to expose the surface of the bony prominence. The extent of the obstruction and where it occurs can then be clearly seen. By means of a curved osteotome, enough of this bone is removed to allow unrestricted motion of the hip in all directions. The roentgenograms in Figures 3-A and 3-B show clearly where the bony obstruction occurs and the appearance of the neck of the femur after it has been removed. One should not attempt to chisel off this protuberance in one large piece. It is a remodeling or plastic procedure; the bone must be removed a little at a time in layers in order to refashion the neck of the femur and to accommodate it to the rim of the acetabulum. The surface should be made slightly concave if this can be done without removing as much bone as would weaken the neck of the femur (Figs. 4-A, 4-B, 4-C, 4-D, and 4-E). Nothing is done to the rim of the acetabulum. One cannot always avoid tearing or fraying the elevated periosteum. If possible, the periosteum should be neatly sutured over the raw surface of the bone in order that the membrane may prevent regeneration of bone growth from the raw, uncovered bone surface.

Patients whose epiphyses are seen, roentgenographically, to be nearly fused require no postoperative protection other than a plaster boot with a crossbar behind the ankle or a plaster spica worn for about one week, so that the extremity will not lie in external rotation. Passive motion to the limit of comfortable tolerance and without irritation is carried out promptly, and active exercises are begun without delay. The patient is

FIG. 4-A

Roentgenogram made October 8, 1953, of C. T., a girl fourteen years old, who had had severe displacement of the left femoral epiphysis with pain and limp for nine months.

FIG. 4-B

FIG. 4-C

Figs. 4-B and 4-C: C. T. Roentgenograms made October 8, 1954. The hip flexed in external rotation and there was complete loss of internal rotation. Abduction was limited. Osteoplastic procedure at the neck of the left femur was done October 14, 1953, without attempting to correct the epiphyseal displacement.

encouraged to be up and about with crutches and weight-bearing, and to discard crutches as soon as he feels he can do without them.

When preliminary roentgenograms show that the epiphysis is not yet fused and that still further displacement might occur, epiphyseodesis by means of a graft of cancellous bone across the center of the epiphyseal plate is also done in order to induce prompt fusion. This takes little additional operative time. The bone which has been removed in order to obtain free motion of the hip may be used for the bone graft instead of obtaining graft material from the crest of the ilium. Although early postoperative active motion is prescribed, hips which have been subjected to this procedure must be protected from weight-bearing until good consolidation has taken place, as in epiphyseodesis. The technique for epiphyseodesis has been described elsewhere [2]. Figures 5-A to 5-D show the combined techniques of osteoplasty and epiphyseodesis.

By this combined operation, restoration of good motion, correction of deformity, and stimulation of prompt fusion can be accomplished in the same operative procedure

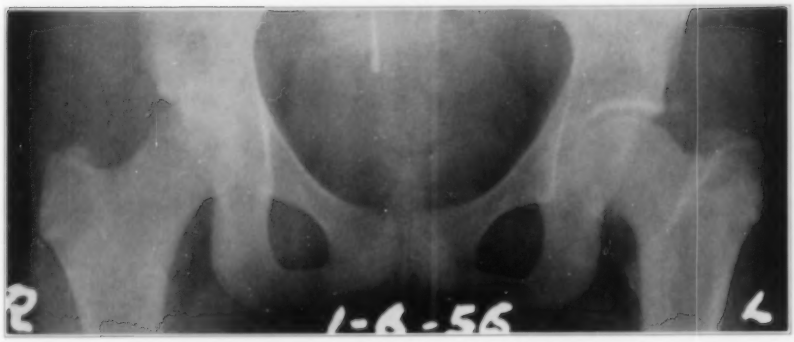

FIG. 4-D

C. T. Roentgenogram made January 6, 1956, two years and three months after osteoplasty. Note that the upper surface of the neck of the femur now is concave with no impingement of the rim of the acetabulum against the neck of the femur.

FIG. 4-E

C. T. Roentgenogram made January 6, 1956. The operation resulted in an excellent joint. The patient had 90 degrees of flexion, normal abduction, and internal rotation was practically normal. There was no appreciable limp.

without subjecting the patient to a secondary osteotomy with the attending postoperative fixation and confinement. Also, it appears that subtrochanteric osteotomy does not improve ability to flex the hip, when this is also a disabling factor, as the remodeling procedure does. As a result of experience and knowledge gained by postoperative observations, epiphyseodesis is now done frequently in conjunction with the osteoplastic procedure at the neck of the femur when roentgenograms show that the epiphyseal plate is not yet obliterated and the epiphysis is not yet fused. Following this combined operative procedure, patients progress rapidly in recovery from limp and in regaining relaxed, painless motion.

We realize that the boundaries between the degrees of displacement and the stages of healing toward ultimate consolidation are not so sharply defined that one can say with certainty that in every instance the major cause of limitation of motion is a bony obstruction or misalignment. Nor can it be said with assurance that consolidation in a patient's hip has progressed to a point when further displacement will not take place. It is also appreciated that pain and muscle spasm tend to disappear in the course of time without treatment, and it is possible that a bony prominence obstructing motion in the hip might eventually become absorbed or otherwise adapt itself and result in no

FIG. 5-A

Roentgenogram made May 1, 1953, of J. S., a girl thirteen years old, who had had severe displacement of the right femoral epiphysis with pain, severe limp, and stiffness of the hip for one year. Flexion was limited to 45 degrees in external rotation. No internal rotation was possible, and there was limitation of abduction.

FIG. 5-B

FIG. 5-C

Figs. 5-B and 5-C: J. S. Roentgenograms made May 1, 1953. The neck of the right femur is seen impinging against the rim of the acetabulum.

permanent serious loss of motion. Bearing these speculations in mind, a conscious effort has been made to select only those patients for operation who presented so severe a malposition of the epiphysis and disability that some kind of operative treatment was essential. In doubtful cases, the decision to perform osteoplasty can be made after examination of the patient under anaesthesia. If good flexion, wide abduction, and good internal rotation are obtained by a reasonable amount of manual traction and stretching in abduction and internal rotation, it is probable that the operation will not be necessary. Occasionally, position may be improved or reduction accomplished even though symptoms of long duration suggest that improvement is unlikely. Good motion may sometimes be obtained without altering the displacement when the displacement is not too severe.

In 1949, remodeling of the neck of the femur was done successfully by one of the authors in three of forty-one patients with slipped epiphysis. It was said then that if further experience with the procedure confirmed these three good results, an important conservative operation would be available for treating long-standing slipped femoral epiphysis with severe displacement and serious limitation of motion. Since that time,

FIG. 5-D

Fig. 5-D: J. S. Roentgenogram made November 5, 1954, eighteen months after the osteoplastic operation done on June 10, 1953. The bone at the neck of the femur which obstructed hip motion was removed, and a portion of it was used as a cancellous-bone graft across the epiphyseal plate. The patient made a rapid recovery. She had no limp, and motion at the hip was normal except for a slight limitation of internal rotation.

Fig. 5-E: J. S. Roentgenogram made November 5, 1954. Restoration of motion at the hip joint was excellent although no attempt was made to correct the malposition of the femoral epiphysis.

FIG. 5-E

experience and follow-up observations on many patients have confirmed these conclusions. Pain and stiffness caused by aseptic necrosis with articular cartilage degeneration is a counter-indication for the operation. Remodeling the neck of the femur could not improve motion with these conditions.

The authors have done twenty-one osteoplastic operations upon twenty patients, one bilaterally. In addition to these twenty-one operations, records and roentgenograms of seven more operations upon five patients have been submitted by other orthopaedic surgeons. Altogether, there have been twenty-eight operations upon twenty-five patients.

The ages of the patients ranged from twelve years to sixteen years, with the one exception of a patient with hypogonadism who was twenty-one years old. In all the patients, displacement of the epiphysis was severe and the duration of symptoms varied from four months to two years. Duration of symptoms, however, is an unreliable factor in estimating accurately how long the displacement has existed and the amount of stability or consolidation there is present in the hip joint. The limitation of motion, the shortening, and the amount of pain varied in the twenty-five patients. In all patients the hip was in a position of external rotation with limitation of internal rotation and abduction. In some of the patients flexion of the hip was present to 90 degrees, but only in the externally rotated position; in others, flexion was greatly limited.

Fourteen patients were operated upon two years ago, or longer. The average length of follow-up was six years. The longest follow-up was fourteen years. This group may be considered to represent long-term results of the procedure. Seven patients have been operated upon during the last two years. Although these patients have had good results and recent patients are doing well, it is too early to include these results in our

series. Besides the patients under our personal care, good results were reported following the seven operations performed by other surgeons. A true end result cannot really be known before middle age, for it cannot be determined before then if the hips treated by this conservative operative method will stand up under the stresses and strains of years of physically active life.

It cannot be expected that limp will be completely overcome, nor that motion will return to normal in all ranges. The coxa vara and the shortening of the extremity caused by displacement which has not been reduced will still remain. For a good result, however, there will be no pain, the patient will walk with the knee directed straight forward, the residual limp will be slight and inconspicuous, and the amount of limitation of motion will not be disabling nor interfere with normal activities. This has been the result in all cases coming under the observation of the authors and in the cases reported in personal communications from several other surgeons. In some patients, there was no limp or appreciable limitation of motion. There has been no evidence of aseptic necrosis, or clinical or roentgenographic evidence of osteo-arthritis. We have had no occasion to explore any of these hip joints postoperatively and it can only be surmised that the raw surface of cancellous bone remaining after the removal of the obstruction becomes covered with a fibrocartilage-like, smooth-surfaced tissue which is not irritating.

FIG. 6

Reproduction of Figure 337, page 382, from *Orthopädische Operationslehre* by Vulpius and Stöffel, published in 1913. The bone above the curved dotted line is the portion of bone which is removed to relieve the obstruction to motion at the rim of the acetabulum.

It was not until we had found for ourselves that patients do well after this treatment and that cervical osteotomy or open reduction are not necessary for restoration of good function, that we learned that Whitman performed this operation in one of eleven cases of adolescent coxa vara which he reported in 1909. The patient was a girl, fifteen years old, whose "disability was complete". "On opening the joint", reported Whitman, "the head of the femur was found to be displaced slightly downward and backward, exposing the sharp angular border of the neck. As the fragments were firmly adherent, the projection was removed and the wound was closed." When the patient was seen several months later, function was perfect with the exception of some limitation of flexion. Whitman did not mention this procedure again in his later writings.

Although a thorough search of the literature has not been made, the one case reported by Whitman and a brief paragraph in Orthopädische Operationslehre by Vulpius and Stöffel, published in 1913, are the only references to this operation known to us. The reference to this procedure by Vulpius and Stöffel is noteworthy since it was illustrated by a drawing depicting the convexity of the neck of the femur and the bony prominence which we remove (Fig. 6).

Key, in 1926, referred to the procedure of chiseling away the projecting upper and anterior border of the end of the neck of the femur in slipped epiphysis. When one con-

siders the history of Key's Case No. 17 and onset of the disability, together with the description of the findings at operation and the operative procedure employed, the poor result in this single case did not justify his conclusion that "in these cases it is not possible to get even an approximately normal joint".

CONCLUSIONS

It has been our experience in twenty-one cases, and hence it is our belief, that the comparatively simple and conservative operation to remove the bony obstruction to motion against the rim of the acetabulum is efficacious in the treatment of slipped epiphysis with severe displacement. Restoration of good motion and function, correction of deformity, and relief from pain is accomplished without the necessity of cervical osteotomy or wedge resection and with little residual limp. This procedure has an important place in the treatment of selected patients with severe slipping of the upper femoral epiphysis.

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DISCUSSION

Dr. Beckett Howorth, Stamford, Connecticut: Open reduction or wedge osteotomy of the femoral neck has been performed many times and by many surgeons since it was first advocated by Whitman in 1909. There have been some good results. However, it is now generally agreed that the risk of aseptic necrosis and of a poor result following these procedures is too great to justify their use, except possibly under very restricted circumstances. Subtrochanteric osteotomy for indirect correction of the deformity has been less commonly used and presents certain technical difficulties, but it has been found safer in that it is much less likely to be followed by aseptic necrosis of the femoral head. The fact that a slipped epiphysis does heal spontaneously, often without marked deformity, pain, disability, or aseptic necrosis, is now more commonly understood and recognized.

Dr. Heyman, Dr. Herndon, and Dr. Strong have been seeking a simple, safe operative procedure for correcting deformity and for improving motion and function of the badly slipped epiphysis which cannot be reduced by gentle manipulation. They have presented a well reasoned and well documented report of twenty-one hips treated by removal of the bony prominence of the projecting margin of the neck, with an adequate preliminary follow-up and analysis. Accordingly, although I have not used the method or had the privilege of seeing the operation or the patients, I can only commend the report and agree substantially with their statements. I would suggest, however, a more detailed and exact analysis of the clinical and roentgenographical findings before operation and at the last examination, and urge them to pursue their plan to continue the procedure and the study. We also have reported the tendency toward spontaneous rounding off of this bony prominence, and would reserve the operation for the more severe deformities, especially the downward rather than the posterior slip.

Dr. Robert J. Joplin, Boston, Massachusetts: I wish to congratulate Dr. Heyman for striving to simplify the treatment of slipped femoral epiphysis which affects adolescent children. To fully correct a slipped capital femoral epiphysis is a most difficult surgical procedure.

Dr. Heyman suggests a procedure for increasing the range of motion in abduction and flexion in a deformed hip joint. However, he admits that he leaves incongruous surfaces and a coxa vara deformity. These ultimately lead to osteo-arthritis which will probably require some type of hip reconstruction or a hip fusion later on in life.

I find it difficult to commend a procedure which leads inevitably to deterioration.

At our meeting in Quebec with The Canadian Orthopaedic Association and The British Orthopaedic Association in 1948, we showed roentgenograms (Fig. 21 in a former publication [b]) of a boy, thirteen years old, who had a slipped capital femoral epiphysis with a projection similar to those which Dr. Heyman has

(Continued on page 407)

Surgical Repair of a Torn Tibial Collateral Ligament of the Knee by Means of the Semitendinosus Tendon (Bosworth Procedure)

Report of Twenty-Eight Cases

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In 1952, Bosworth described a procedure for repairing a torn tibial collateral ligament by rerouting the semitendinosus tendon to replace the torn ligament in both position and function. Earlier Phillips (1914) and McMurray (1919) had developed a similar procedure in which the gracilis or sartorius tendon was used. The latter operation was reviewed by McConville in 1950. The procedure described by Bosworth is physiological, for the material used is an available, viable, strong tendon which is not completely devoid of its blood supply. In other surgical procedures for repairing torn ligaments, fascia or tendon material, removed partially or completely from its normal position, is used to "suture" the femur to the tibia.

Normally the distal end of the semitendinosus tendon is inserted, along with the tibial collateral ligament, into the tibia. Merely by the formation of a bone flap in the medial femoral condyle and by the insertion of the tendon behind this flap, the torn ligament can be replaced both anatomically and functionally.

While stationed at Fort Bragg, North Carolina, an airborne troop center, the author encountered an unusually large series of severe knee injuries over a two-year period. Most of these injuries responded to the usual conservative treatment consisting in immobilization in a plaster-of-Paris cast—for three weeks in less severe cases and for five to eight weeks in those in which gross instability was present. If the patient did not respond to this regimen or if he had severe prolonged instability, surgery was performed. Five patients with early, complete ligamentous rupture were also subjected to surgery.

Indications

The primary prerequisite for the use of the Bosworth procedure is, of course, lateral instability of the knee due to a lax or torn tibial collateral ligament. In most patients with this injury there are also varying degrees of anteroposterior instability and signs or symptoms of a pathological condition in the medial meniscus.

In cases of fresh severe injury with complete tear of the ligament, it is our practice to consider surgery early. At surgery both repair of the ligament, if possible, and rerouting of the tendon is performed. It has been found that the severe reactions which develop immediately after the injury — swelling, hemorrhage, and friability of the tissue — makes the procedure more difficult.

Preoperative Care

It is felt that a good functioning quadriceps femoris is essential to success. Therefore, before surgery, an intensive course of physiotherapy is given, first, to build up quadriceps power and, second, to restore full motion if full motion is lacking. Preferably, before surgery is undertaken, the patient should be able to lift twenty to twenty-five pounds to a position of full extension ten consecutive times. The only exception is patients with

fresh complete tears for whom quadriceps setting exercises are emphasized from the outset. If prolonged immobilization has preceded surgery, the patient is also given whirlpool therapy to improve the condition of the skin and the local circulation.

OPERATIVE PROCEDURE

Under tourniquet control, an oblique incision, four to five inches long, is made over the medial aspect of the knee. The incision is begun at the tibial plateau, one inch medial to the border of the patellar tendon, and is extended proximally to pass midway between the anterior and posterior limits of the femoral condyle (Fig. 1).

Because of the extremely high incidence of injury to the medial meniscus in these patients, it is strongly urged that the joint be explored. This is done through a vertical

FIG. 1

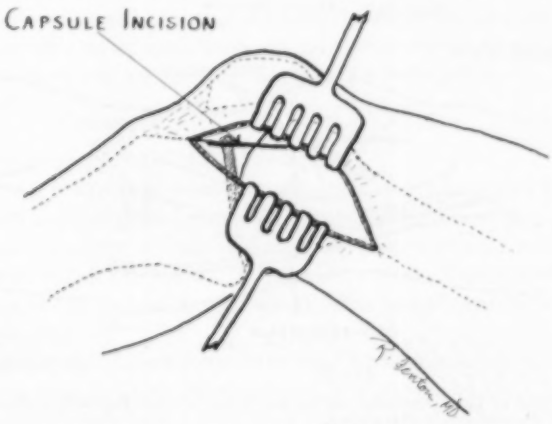

FIG. 2

Fig. 1: Incision used in the Bosworth repair of a torn tibial collateral ligament (seen from the medial aspect of the knee).

Fig. 2: This line drawing shows the capsular incision made following retraction of the skin edges. A second capsular incision may be made posterior to the ligament if it is desired.

incision in the capsule and synovial membrane at the distal end of the wound (Fig. 2). After the joint has been examined, the medial meniscus is removed, if necessary, and the openings in the synovial membrane and capsule are closed in layers.

With the knee fully extended, a posterior flap is constructed, a gap being left so that a finger may be inserted to explore the posteromedial structures. Two tendons will be palpated. The first, the gracilis, may be identified by the fact that it has muscle fibers extending as far distally as the medial femoral condyle. The second, and more posterior, tendon is that of the semitendinosus, which has no visible fibers at this level. Either tendon can be used, although the author prefers the semitendinosus. The tendon to be used is mobilized proximally and distally, care being taken to avoid damage to the saphenous nerve proximally and to the tendon attachment at the pes anserinus distally. The author feels that the success of the operation is directly proportional to the tightness of the transferred tendon and that, therefore, care should be taken not to free the tendon too extensively.

By means of a scalpel, a wedge is cut in the soft tissues over the medial aspect of the femoral condyle. This wedge is made with its apex directed anteriorly, the point of the apex being placed within one-half to one-quarter of an inch of the anterior border of the femoral condyle. The base of the wedge is posterior and lies midway between the anterior and posterior limits of the condyle at the point of insertion of the tibial collateral ligament. The base is not cut (Fig. 3).

By means of a sharp osteotome one and one-half inches wide, a similar wedge is cut in the bone. This wedge follows the lines of the wedge in the soft tissues, and its base, which is one to one and a half inches long, is left intact. The triangle of bone thus formed is carefully elevated in order to expose the bed of raw cancellous bone below. All loose cancellous chips are removed. With a medium (one-quarter inch) gouge, grooves are made at either end of the base of the bone flap, extending down into the raw bone (Fig. 3). Two fine holes are drilled into the raw bed on either side of the apex of the bone flap, and two more holes are drilled into the bone flap itself. No. 9 stainless-steel wire sutures are then passed through the holes in the raw cancellous bone. The tendon is passed behind the sartorius and forced over and behind the bone flap. If the procedure has been done correctly, this step will be difficult. If this step is easy to do, it means either that the tendon

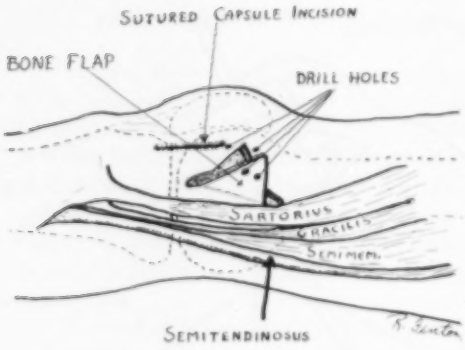

FIG. 3

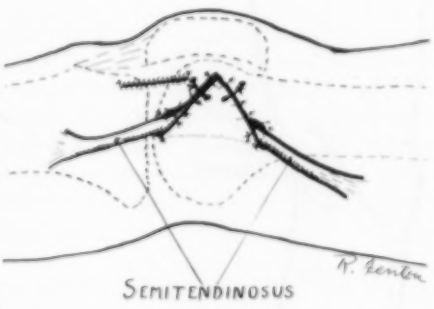

FIG. 4

Fig. 3: This illustration shows the triangular bone flap with a groove at either side of its base. The anatomy of the muscles is also shown.

Fig. 4: The semitendinosus tendon has been placed behind the bone flap and the latter has been resutured in its original position.

has been freed too extensively or that the bone flap has been placed too far posteriorly. When the tendon is in place behind the bone flap, it should lie in the two grooves on either side of the base, allowing the flap to be forced back into its bed. The wire sutures are passed through the two holes in the flap, the flap itself being held firmly against its bed by the operator's left thumb. An assistant then ties the two sutures together, and the tendon and bone wedge are thus secured in place (Fig. 4). The soft-tissue flap is replaced and fixed with interrupted No. 1 or No. 2 chromic catgut sutures. At the two angles of the base of the triangle, the sutures are passed through the tendon, which is thus fixed even more firmly in its new position. The wound is then closed in layers.

A plaster-of-Paris cast is applied from the toes to the groin with the knee in full extension. Care is taken that no flexion is allowed at any time after the tendon has been placed in its new position. The tourniquet is released.

POSTOPERATIVE CARE

After the operation the limb is elevated and the usual postoperative measures are carried out. Quadriceps setting exercises are begun as soon as the patient is able to cooperate. These exercises are done hourly during the waking hours. If the plaster must be split because of swelling despite elevation and sympathetic-nerve blocks, care must be taken that no flexion occurs at the knee joint.

On the tenth day after operation the sutures are removed and a toe-to-groin plaster cast with a walking heel is applied. Once again flexion at the knee is carefully avoided. When the plaster is dry, full weight-bearing is encouraged.

Immobilization is maintained for three to five weeks postoperatively. As we gained experience with the procedure, we tended to continue the immobilization for the full five weeks, since it did not seem to delay the return of motion and it did guarantee more secure healing.

After removal of the plaster-of-Paris cast and mobilization of the knee, emphasis is placed upon progressive resistance exercises and the maintenance of full extension. We feel that the patient should be able to lift at least twenty-five pounds to a position of full extension ten consecutive times. Flexion to at least 90 degrees should be obtained by three months after operation.

It is hoped that following this type of surgical repair the tendon will maintain its strength and will not stretch, as tendons often do following tenodesis. Until follow-up has been sufficiently long to ascertain whether or not such stretching will occur, however, it might be wise if the patient were requested to avoid strenuous activity for at least a year or a year and a half. In the author's series many patients did resume strenuous activity less than a year after surgery, but, as yet, no apparent ill effect has been noted.

RESULTS

The results were rated according to the following criteria:

Excellent: To be included in this group the patient must have a stable knee and his range of motion must be from 180 degrees of extension to at least 80 degrees of flexion (100 degrees of active motion from a position of full extension). He should be able to lift at least twenty pounds to a position of full extension ten consecutive times. Functionally the patient must be able to return to his former duties, which often include sports, full field duty, and even parachute jumping.

Good: To be included in this group the patient must have a joint which is stable when fully extended. His range of motion must be from 180 degrees of extension to at least 100 degrees of flexion (80 degrees of active flexion from a position of full extension). The soldier should be able to return to duty, although he may have some disability which will prohibit long marching, parachute jumping, or contact sports. In three instances in the author's series a patient with a good result was discharged from the Army because his enlistment period was up, not because of any disability.

Poor: This group includes those patients in whom stability is not obtained. In one case in the author's series instability was severe enough to require separation from service and in another the patient was able to do only sedentary work.

In the author's series there were twenty-eight patients upon whom surgery was performed. For eight of these patients follow-up was not available, seven having been operated upon less than one month before the time of writing and one having been transferred to another post shortly after the plaster was removed. This left twenty patients for whom there were good follow-up records. Of these, there were eight in whom the results qualified as excellent (40 per cent). This group included four parachute jumpers, one motorcycle military policeman, and three infantrymen. In ten of the other patients the results were classified as *good* and in two they were classified as *poor*.

One of the two patients with a poor result had suffered a complete dislocation of the knee. He had previously been immobilized for two months and had been left with a grossly unstable knee. The Bosworth procedure was performed to replace the tibial collateral ligament and two weeks later an Edwards procedure was done to replace the fibular collateral ligament. After surgery the knee was reasonably stable when fully extended and the condition was improved. When the knee was even slightly flexed, however, it gave way, which meant that the patient had to walk stiff-legged. He was released from service as permanently disabled for duty.

The second patient with a poor result had got out of bed on the eighth postoperative day, at which time his plaster was off in order that the sutures might be removed. He had

walked to the lavatory and while doing so had felt a snap; the leg had given way and he had fallen. After several more weeks of immobilization, complete lateral instability was still present, but he had refused re-exploration. At the time of writing he was still in the service on limited duty.

One of the patients with a result that was rated *good* was an officer with advanced posttraumatic arthritis in both knees. He was greatly benefited by surgery, but since his job required strenuous activity and his future in the Army was limited, he chose retirement.

Five of the patients were operated upon less than one month after injury, the earliest operation being done three days after injury. Of these patients three had excellent results and two had good results. In four patients surgery was performed one to six months after the original trauma. In three of these patients the result was excellent and in one it was good. Five men were operated upon six to twelve months after the initial accident. The two patients with poor results were in this group. Two of the others in this group had good results and only one had an excellent result. Six of the patients received surgery more than one year after injury, the longest period to elapse between injury and repair being ten years. In this group one result was considered excellent and five were considered good.

On the basis of these findings it would seem that the results in patients treated early are somewhat superior to those in patients treated later.

DISCUSSION

In the author's series the Bosworth procedure was given a severe test. A soldier's routine life is a strenuous one and the fact that sixteen of twenty patients returned to duty, eight of them to unlimited duty, speaks well for the operation. Three other patients were also fit for duty but were separated from service because their enlistment had expired.

The only changes made in the technique as described by Bosworth were: (1) grooves were made on either side of the bone flap in order that the flap would fit better and bulge less when the tendon was in place and (2) the postoperative period of immobilization was increased from three to five weeks and a plaster-of-Paris cast was used. It should be re-emphasized that the tendon must be made sufficiently tight so that its placement behind the bone flap is difficult. It is also important that the base of the bone flap be in line with the femoral attachment of the tibial collateral ligament.

In one instance in the author's series the bone flap split off completely. The problem that resulted was overcome by inserting the tendon itself into the raw bone bed, wire sutures being driven through the bone and tendon. The broken flap was then placed over the tendon in the raw bed and was reinforced with the soft-tissue flap in the usual manner.

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Long-Term Results in the Bucket-Handle Acetabuloplasty *

BY I. WILLIAM NACHLAS, M.D., BALTIMORE, MARYLAND

About twenty-five years ago there were in use a number of surgical procedures which were designed to produce a bone platform or shelf in order to stabilize a congenitally dislocated hip. There were some favorable reports concerning these procedures, but all too frequently the results were not satisfactory.

In several of the operations the shelf consisted of a bone projection extending laterally from the side of the ilium. This projection did not always maintain its initial length, being frequently resorbed until only a useless nubbin of bone remained. When it did retain adequate length, it often was so narrow that its supportive value was largely limited to one plane—as a result of which it did not prevent riding up of the unstable femoral head either anteriorly or posteriorly. Furthermore, the flat ledge or "terraced" roof of this type of projection did not constitute a satisfactory cap for the spherical femoral head. It became obvious that the objective of treatment should be a socket which is contoured to fit the femoral head and which has sufficient depth to house it securely.

A procedure, the bucket-handle acetabuloplasty, was developed in an attempt to meet these requirements. In essence this plastic surgical procedure was designed to convert the deformed acetabulum into a hemispherical socket with adequate depth. The details of the operation have been enumerated in the original article [1], but a brief review of the principles and procedure is in order.

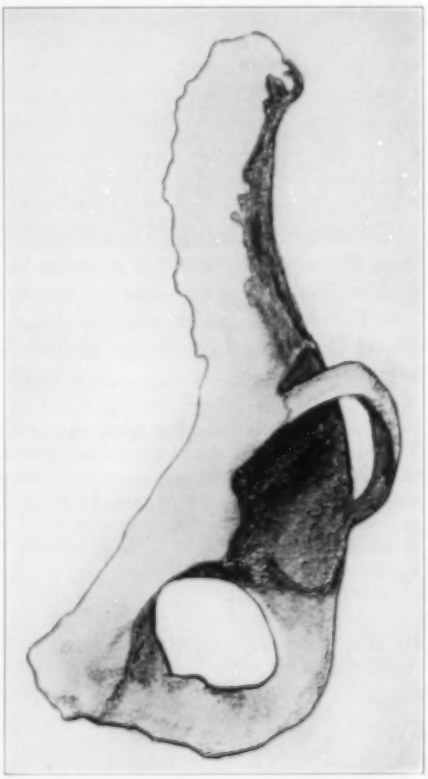

FIG. 1

This drawing shows the hip after the rim of the upper portion of the acetabulum has been swung out like a "bucket handle".

From geometry we learn that a hemisphere can be projected by swinging a half circle on its ends through an arc of 180 degrees. This concept can be applied to the acetabulum. If the rim of the upper half of the acetabulum is cut free except at its anterior and posterior ends, a half circle of bone can be swung out like the handle of a bucket (Fig. 1). The gap that is left can be filled by a graft from the iliac crest. Since the circulation of the live bone in this area is good, it may be expected that there will be adequate callus to heal the operative fracture.

At operation, the femoral head is placed deep in the acetabulum, where it is held by means of abduction of the limb. The rim of the acetabulum is then osteotomized and is swung out as far as indicated, following which a bone graft is placed in the gap. A plaster-of-Paris spica, applied with the limb in abduction, is used for immobilizing during the

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 31, 1956.

healing period. The femoral head serves as a mold for the newly formed callus. Properly done, this operation should yield a hemispherical socket.

There is one important preliminary requirement. Since the operation is a reconstruction of the acetabulum, the femoral head must first be brought down to the level of the acetabular socket. This may require the earlier use of traction or even the performance of a relaxing operation. If this prerequisite is met, the operation is suitable not only for congenital dislocation of the hip but also for other types of chronic dislocation. The conditions of the group of patients upon whom this procedure was originally used included poliomyelitic dislocation, "wandering acetabulum", and congenital dislocation.

The practical value of this operation on a short-term basis has been reported previously [1]. The early results were good and it was particularly gratifying to find that it had been possible to maintain stability even in patients in whom earlier shelf operations had failed. The conditions in the author's series were not easy to treat, particularly since the patients were relatively old. It was encouraging to find that after a few years the hips had remained stable. Nevertheless, the question was raised, "How will these hips hold up in the long run?" Since intra-articular fractures had been made, it was also asked, "Will useful mobility be retained?"

To answer these questions the patients were re-examined and the long-term results were determined. To avoid personal bias, the findings of other qualified orthopaedists were studied—except in the two cases in which only the author's findings were available.

The bucket-handle acetabuloplasty was performed upon nine patients prior to World War II. The youngest of these patients was four years old and the oldest was twenty-five.

The first patient operated upon was a fourteen-year-old boy with paralytic dislocation of the hip following poliomyelitis. He had had three previous surgical procedures, including a shelf operation, but none of these procedures had been successful. In December 1934, an acetabuloplasty was performed. The patient was last examined in April 1955, when he was thirty-five years old. His hip was found to be stable, there were no symptoms, and there was a normal range of passive motion. Roentgenograms showed an imperfect acetabulum which was high and displaced laterally, but which covered three-quarters of the femoral head with a solid roof (Figs. 2-A and 2-B).

The second patient was a six-year-old girl with congenital dislocation of the hip. Two attempts at closed reduction had been made previously without success. The acetabuloplasty was performed in 1934. At the time of her last examination in December 1954, she was twenty-six years old and had been followed for twenty years. She was able to participate in all normal activities and was conscious of her hip only after considerable activity (such as is involved in a day's shopping tour); at such times she limped slightly. Examination revealed that there was a shortening of one inch but that the hip was stable and the range of motion was normal, being fully as good as that on the unaffected side. The findings of the Trendelenburg test were normal, unless she rested her weight on the affected limb for more than a minute or two, following which the findings slowly became positive. The roentgenograms showed that the acetabulum was somewhat high, but that it covered the femoral head with a well rounded surface (Figs. 3-A and 3-B). There was narrowing of the articular cartilage space and some increased density of the acetabular area.

The third patient was a twenty-five-year old woman with a painful right hip which "gave way" on weight-bearing. Because she had a wandering acetabulum and a deformed femoral head and neck, the diagnosis was probable congenital dislocation. In the light of our present knowledge it is felt that the condition may actually have been dysplasia of the hip. Acetabuloplasty was performed in 1935, and the results were evaluated in 1955 (at which time she admitted she was forty-seven). On the later occasion there was evidence of generalized polyarticular rheumatoid arthritis (with psoriasis) which was said to have been active for fourteen years. She had full use of her right hip, although she had some pain and limped slightly. The examination revealed advanced polyarticular rheumatoid arthritis. She limped mildly in spite of the fact that her hip was stable and could not be moved out of position by manipulation. The limb on the affected side was one inch short and could not be rotated internally beyond the neutral position. Movements of the hip were excellent except for internal rotation. Roentgenograms revealed that the coverage of the femoral head was adequate and that the contour of the acetabular roof was good; they also revealed that there were changes in the joint space and adjacent bones which were indicative of osteo-arthritis. The deformity of the head

FIG. 2-A FIG. 2-B

Fig. 2-A: Roentgenogram, made before the acetabuloplasty, of a patient with paralytic dislocation of the hip.

Fig. 2-B: Roentgenogram made twenty-one years after the acetabuloplasty.

and neck which had been previously found was still present. Since the range of external rotation was greater than normal (Figs. 4-A and 4-B), it was felt that the limitation of internal rotation was probably caused by the torsional changes at the upper end of the femur rather than by any defect in the acetabulum.

Our records indicate that, prior to World War II, acetabuloplasty was performed upon six additional patients. Only four of these patients could be traced, however. One of the missing patients, aged twenty-two, had had a poliomyelitic condition, while the

FIG. 3-A FIG. 3-B

Fig. 3-A: Roentgenogram, made before the acetabuloplasty, of a patient with congenital dislocation of the hip.

Fig. 3-B: Roentgenogram made twenty years after the operation.

other, aged five, had had congenital dislocation of the hip. Three of the four patients who could be traced had had congenital dislocation of the hip; these patients were five, four, and seven years old at the time of operation in 1937, 1938, and 1942, respectively. The fourth patient who could be traced had had a poliomyelitic condition and had been operated upon in 1938, when nine years of age. The findings obtained by recent examinations of these patients are listed in Table I.

SUMMARY OF FINDINGS

1. Hip stability was maintained in every case.

2. Pain was negligible except in the patient with generalized rheumatoid arthritis. Three other patients reported some pain, but said that the discomfort occurred only after excessive activity and then was only mild.

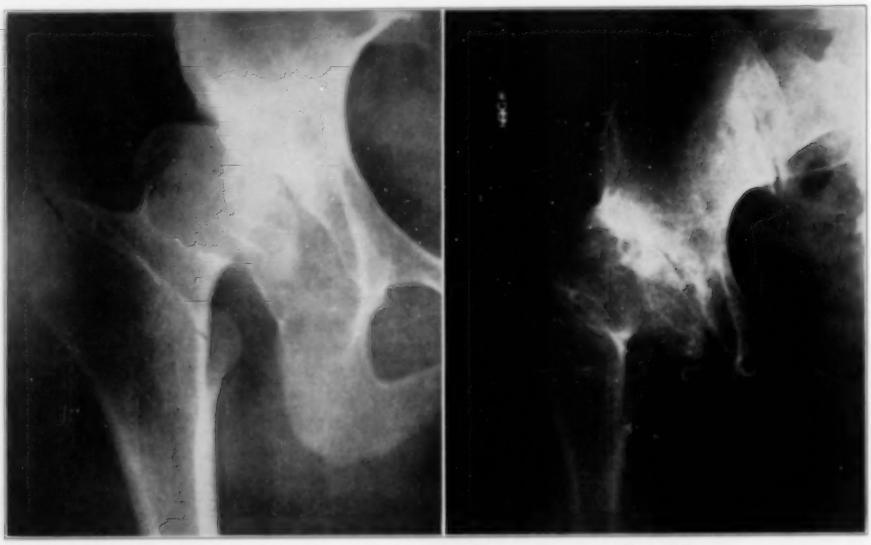

FIG. 4-A FIG. 4-B

Fig. 4-A: Roentgenogram, made before the acetabuloplasty, of a patient with dysplasia of the hip.
Fig. 4-B: Roentgenogram made twenty years after the operation.

3. In every instance the range of motion was good. In the one patient with some restriction of internal rotation, there was a better-than-normal range of external rotation.

4. Limp was found in three patients. Two of these patients reported that the limp was slight and appeared only after excessive activity, while the third indicated that the degree of limp varied with the degree of activity of her rheumatoid arthritis. When one of the two patients with mild limp stood on her affected limb more than a minute, the findings of the Trendelenburg test became positive.

5. Shortening of the affected limb was found in practically every patient, and in three patients it was as much as one inch. The relatively high position of the acetabulum, as shown in the roentgenograms, is probably the explanation of this shortening.

6. The roentgenograms showed that in all the patients the femoral head was in the socket. They also showed, however, that the normal anatomical pattern of the acetabulum had usually not been restored. Most of the acetabula were higher than those on the unaffected side, and in several patients there was slightly less than normal coverage of the head, as shown by osseous acetabular shadows (we did not make arthrograms to determine if cartilaginous extensions existed.) Obliquity of the weight-bearing segment was

TABLE I

Patient	Diagnosis	Early Treatment	Age	Date of Operation	Date of Examination	Activity	Symptoms	Mobility	Stability	Trendelenberg	Shortening	Last X-ray
D. O.	Poliomyelitis.	Soutter; tenotomy and manipulation; shelf operation, closed reduction.	14	4/18/34	4/13/55	Works; wears paralytic brace *.	No pain, no telescoping.	Slightly better than in normal hip.	Good.	No record.	No record.	4/13/55. Stability maintained. Acetabulum high, curved, covers ¾ femoral head. Contour of head, fair. Coxa valga.
T. M.	Congenital dislocation.	No record.	6	12/12/34	12/54	Normal.	Limps only when tired.	Slightly better than in normal hip.	Good.	Slowly positive.	1 inch.	12/18/54. Stability maintained. Acetabulum high, curved, good coverage of femoral head. Contour of head, good. Slight torsion.
A. R.	Dysplasia, wandering acetabulum.	Analgesics.	25	2/14/35	4/6/55	Normal.	General joint pain and swelling.	Flexion: 90° active, 110° passive. Internal rotation: to 0°. External rotation: better than normal.	Good.	No record.	1 inch.	4/6/55. Stability maintained. Acetabulum high, curved. Better than normal coverage. Coxa magna. Osteo-arthritis (?).
B. L.	Congenital dislocation.	None.	5	3/31/37	3/19/54	Normal.	None.	Flexion to 80°. Otherwise normal mobility.	Good.	Negative.	Slight.	11/21/55. Stability maintained. Acetabulum high, curved, covers ½ femoral head. Head rounded, torsion.
L. V.	Congenital dislocation.	Two closed reductions; traction; traction on unaffected limb.	4	3/2/38	12/14/54	Normal.	Slight pain and limp when tired.	Some limitation of rotation.	Good.	Negative.	1 inch.	12/14/54. Stability maintained. Acetabulum high and good curve. Anteversion.
H. F.	Poliomyelitis.	Hip operation; shelf (?); foot stabilization.	9	3/9/38	10/43	Walks with paralytic brace *.	None.	No record.	Good.	No record.	No record.	11/12/40. Stability maintained. Acetabulum curved with horizontal roof covering ¾ femoral head. Anteversion of femoral head and neck.
R. W.	Congenital dislocation.	None recorded.	7	2/11/42	12/54	Normal.	For last month, slight pain on extreme activity.	Normal.	Good.	Negative.	Less than ½ inch.	12/13/54. Stability maintained. Acetabulum curved, covers ½ femoral head. Head flattened.

* A long double upright brace with a gravity-lock joint at the knee and a limited-motion joint at the ankle.

noted in three of the sockets, but the curves of these segments were smooth. One acetabulum showed apparent lateral lipping with osteo-arthritic texture in the bone and narrowing of the cartilage covering (the appearance of this acetabulum would lead one to expect limited abduction, but this was not found on clinical examination). Varying degrees of excessive torsion of the femoral neck and head were noted in three of the roentgenograms, and in two some distortion of the femoral head was seen. It is noteworthy that the appearances of the hips in the roentgenograms did not indicate the excellent function which had been obtained.

EVALUATION

Since satisfactory correction can often be obtained by simple closed reduction if the patient is very young, none of the patients in this series was subjected to the acetabuloplasty in infancy. The youngest patient was four years of age; this patient had previously had two closed reductions, but the hip had not remained reduced. The other patients were five years of age or older. In two of them, earlier open reductions had been done but had failed. By the time the patients were subjected to the acetabuloplasty, they were already old enough to have adverse secondary changes.

Another factor that is worthy of consideration in the evaluation of the operative results is the age of the patient at the time of the last examination. The age at which obvious degenerative changes usually first develop in the normal individual is considered to be forty. In the author's series only one patient was over forty (the forty-seven-year-old woman) and the next oldest was thirty-five at the time of his last examination. Neither of these patients showed clinical evidence of osteo-arthritis, although the roentgenograms of the older patient did show changes indicative of this condition. Another report, possibly twenty years later, should be made to show the effects of the "degenerative era".

Bearing these points in mind, one must conclude that the bucket-handle acetabuloplasty has been helpful in producing fairly stable joints in hips that were problems. Although the roentgenograms did not reveal normal bone contours, and although there were shortenings of the limb of up to one inch, the patients, after fourteen to twenty-one years, had almost painless and well functioning hips.

SUMMARY

On the basis of these observations, it appears that in patients with chronic hip dislocation due to an inadequate acetabulum, a satisfactory socket can be made by a simple reconstructive operation. Provided that the femoral head has been brought down to the level of the socket, stability of the hip can be obtained, even in patients in whom other standard procedures have failed. In this series the limb shortening was not always overcome but a well functioning joint without appreciable loss of motion or significant pain was achieved in every case.

1. Nachlas, I. W.: Acetabuloplasty for Dislocation of the Hip. Southern Med. J., **32**: 565–571, 1939.

DISCUSSION

Dr. Allen F. Voshell, Baltimore, Maryland: Any attempt to develop a better method of stabilizing hips with unreduced dislocation, or any similar condition, by producing a satisfactory support is worthy of serious consideration. Dr. Nachlas has presented a few long-term results obtained by a variation of the osteotomy of the superior surface of the acetabulum. I believe he should be commended on his willingness to wait for twenty years before evaluating and reporting his results. He is still young, and, therefore, may be able, ten or twenty years from now, to report the real results.

It is difficult to draw any final conclusions from this report, for the series was small and, therefore, an analysis of all possible eventualities cannot be made. Furthermore, I do not know whether the procedure has been tried by others and, in the long run, it is the combined experience of many surgeons which establishes the value of an operation for universal use. Nevertheless, the proof of the pudding is in the eating and

certainly, as Dr. Nachlas has pointed out, few of his patients had any pain following the operation and all had stable hips. Limp was minimal, indicating that better function, if nothing else, was obtained and that the patients were more comfortable.

It would seem to me that it would be difficult to fix a bone graft between the acetabulum and its separated rim in such a manner that it would remain stable until new-bone formation occurs. I would wonder, therefore, whether it might not be safer and easier to try to form more of a shelf. I think that it might have helped in evaluating the results obtained in this series if lipoidal injections or stereoscopic roentgenograms had been made in order to determine whether the curved shelves remained in the desired positions.

Dr. Alvin J. Ingram, Memphis, Tennessee: Before attempting to evaluate this specific technique for the correction of non-traumatic dislocation of the hip, we should briefly consider what we expect to accomplish by such an operation, what alternative methods are available, and how the results of this operation compare with the results of other techniques.

The primary aim of reconstructive operations designed to correct non-traumatic dislocation of the hip should be the creation of normal anatomical relationships within the articulation. Following the operation, the joint should be stable, there should be no pain, limp, or traumatic arthritis, and the range of motion should be at least adequate for function, if not normal.

The different operative procedures for correction of this condition can be classified on an anatomical basis.

Intra-Articular Operations

The procedure discussed in this paper can be classified as an intra-articular acetabuloplasty. We ourselves have not attempted this operation for two main reasons, both of which are theoretical. First, it would seem that when the bone grafts are packed into a defect produced by the osteotomy, some roughening of the articular surface of the acetabulum would result; it would seem that this incongruity would almost certainly predispose the joint to traumatic arthritis. Furthermore, the defect is made in the area of maximum acetabular weight transmission, a factor which would also seem to predispose the joint to arthritic changes. My second reason for not having used this technique has been the fear of breaking the "bucket handle" at one of its points of attachment. In such an event, I would think postoperative fixation would be most difficult, to say the least. From Dr. Nachlas' results, it would appear that my fears have not been well founded.

The second type of intra-articular operation that has been used to treat non-traumatic dislocation of the hip is Colonna's procedure to deepen the acetabulum. He himself has reported some good results, but several other authors have found that such procedures are followed by the development of intra-articular adhesions and stiffness of the joint.

Extra-Articular Operations

There are three types of extra-articular operations, namely, the shelving operation, osteotomy to correct anteversion, and osteotomy to correct valgus deformity.

Most of the shelf operations that are popular today are variations of the Lance technique described by Haas. In this procedure the ilium is incised around the periphery of the acetabulum, and the acetabular roof is levered distally in a concentric manner toward the femoral head. The acetabular fragment is maintained in the desired position by bone grafts.

Ponseti and others have pointed out that poor results following shelf operations are related more directly to the eccentric position of the femoral head than to the size of the shelf produced. If the femoral head is displaced laterally and superiorly, the abductor muscles become inefficient with the result that limp develops, and positive Trendelenburg signs are found on examination. The best results following shelf operations occur in patients in whom the femoral head is close to the center of gravity, or, in other words, in whom the Y coordinate on the affected side is not more than one centimeter greater than that on the normal side. With the methods available at present this rigid requirement is satisfied in a discouragingly small percentage of cases.

The performance of osteotomy to correct anteversion cannot be expected to correct a deficiency of the acetabulum; in our opinion, however, it will often prevent redislocation. The older the child and the more severe the anteversion, the greater the need for osteotomy to correct it. We prefer to do the osteotomy at the level of the trochanter rather than at the supracondylar level.

The possibility of doing an osteotomy to correct coxa valga should not be overlooked, especially in patients with paralytic dislocation of the hip. In our opinion, this is the only technique by which a femoral head within an acetabulum covered by hyaline cartilage may be shifted toward the center of gravity of the trunk. The ideal postosteotomy angle will probably be about 135 degrees. This operation has certain mechanical features which justify its consideration.

If it is not possible to create normal or near normal intra-articular relationships because of severe primary or secondary changes, then the surgeon must face the realization that at best he can only expect to improve a bad situation.

Dr. Nachlas has been conservative in his estimation of the indications for this operation and in his evaluation of the results obtained in his relatively small series. He reported that stability had been obtained and that the hips had good or normal motion and were without significant pain. Only three of his patients exhibited a limp on examination. The roentgenographic appearance of some of the hips would lead one to expect that arthritic symptoms will ultimately appear. The fact remains that these patients have had from fourteen to twenty-two years of satisfactory service from their hips—a result which in itself renders this operation worthy of serious consideration.

Dr. Nachlas (closing): It should be emphasized that the cases reported in this paper were not chosen at random, for all of the patients who had been operated upon within the time interval selected for this study were included.

The operation is not difficult. Occasionally one end of the bucket handle may break, but this broken end can be fastened down if necessary. Bone healing in this area is good. The capacity of bone to fill a gap in the acetabulum with callus was tested in the following manner: in one patient, instead of the osteotomy gap being filled by a full graft, a small plug of bone was inserted in one corner to serve as a wedge which would maintain the position of the bucket handle. Following this procedure the acetabulum healed satisfactorily.

The use of osteotomy of the femur in order to correct a rotational deformity is a separate problem and should be discussed elsewhere.

DISCUSSION

Vitallium-Mold Arthroplasty

(*Continued from page 248*)

Dr. J. E. M. Thomson, Lincoln, Nebraska: In our experience, the use of the cup arthroplasty is more suitable in young patients; in patients over sixty, complications and the need for revisions have discouraged our use of cup arthroplasty. A critical analysis of cup arthroplasties performed in the treatment of painful osteo-arthritis in old people resulted in our turning to the use of a femoral-head prosthesis six years ago. From the use of the prosthesis we have had a measure of satisfaction. However, we are not convinced that it is right to sacrifice so much of the head and neck of the femur as is necessary with the use of a metal replacement.

Dr. Aufranc's review of 1,000 patients who had had cup arthroplasties is informative and interesting. Much more information is needed, however, in order that we may know in what type of disabled hip and in what age group the cup arthroplasty is most useful. One might assume from this report that cup arthroplasty is the operation of choice in any hip disability.

When one realizes the many months of convalescence and economic loss involved in this surgical procedure, one cannot but help admire the more than satisfactory doctor-patient relationship implied in the 62 per cent of patients with unsatisfactory results who were either enthusiastic or satisfied with the result obtained; one cannot help but admire the conviction in the 22 per cent of the patients who accepted one or more surgical revisions. After supplemental surgery, apparently only 5 per cent were improved.

It is unfortunate that the universal inadequacy of our method of measuring preoperative disability greatly hampers the effort to know the improvement in the patient as a result of ensuing surgery. As Dr. Aufranc pointed out, the patient himself is of little help.

When one puts a movable metal contrivance into an old septic hip joint, he is courting danger. Such joints we know from bitter experience are no place for metal cups or prostheses.

What had been hoped for in Dr. Aufranc's presentation was an analysis of the specific pathological conditions of the hip and at what ages a cup arthroplasty is most suitable. With this information from such a large series of arthroplasties, we could much better appreciate the value and place of cup arthroplasty.

Dr. Carl E. Badgley, Ann Arbor, Michigan: In the properly selected patient, the operation properly performed can produce, under the guiding influence of the Vitallium mold, a functional hip joint. It must be recognized that the surgical principles of repair must not be disregarded. It takes time and patience with motion and rest at the right time, a long period of non-weight-bearing, carefully supervised walking with crutches and later walking with a cane until the hip structure whose component parts have been molded to fit one another is fit to bear weight.

Our experience of eighteen years demonstrates that, as a rule, once a cup arthroplasty has been successful, it remains so.

The Surgical, Social, and Economic Aspects of a Unit Hand Injury *

BY WILLIAM METCALF, M.D., AND WILLIAM WHALEN, M.D., NEW YORK, N. Y.

From the Hand-Plastic Surgery Section of the Surgical Service of St. Vincent's Hospital, New York

The advent of antibiotics eliminated anatomically destructive infection as a serious problem in hand surgery. The widening mechanization of industry and agriculture has increased the frequency of injuries to the upper extremities and to the hands; this brought about the development of the principles and methods of reparative and reconstructive surgery of the hand. The application of new principles and new methods of hand surgery was tremendously accelerated by the needs and demands of World War II. In contrast to these dramatic achievements in major hand surgery, the problems of reparative surgery in the so-called minor injuries of the hand received scant attention.

The loss of function and earning capacity in major injuries are obvious and are well documented. However, the minor and less spectacular injuries may constitute a more serious source of economic loss because of their greater incidence. The resulting insidious loss of many small units of working hours, which do not seem important individually, amount to an appreciable loss over a period of time.

During the past five years the authors have cared for a large number of so-called minor injuries of the hand. To determine the social and economic aspects of this type of injury, the case records of a homogeneous group of 240 patients were studied and analyzed. This group of patients had all been treated for injuries to, or amputations of, a distal phalanx. Relatively trivial injuries were not included. Crushing lacerations with open fractures of the phalanx, avulsion of the nail with underlying rupture of the nail matrix and exposure of the bone, crushing injuries with multiple flap formation exposing the bone, and partial or complete amputations of the distal phalanges were the injuries included in this study.

SOCIAL ASPECTS

The source of the patients comprising the group is a residential-industrial area in which the Hospital is situated. The industries in this area produce small consumer items and goods, and the factories use power presses, printing presses, wood, metal, and plastic working machinery, and meat, cloth, and paper-cutting machines. The labor employed is unskilled, semi-skilled, and skilled.

The causes of the accidents could not always be given nor were those given necessarily true. Many patients claimed that the safety appliances of their machines had been removed or were not in working order. Others admitted to daydreaming and to being distracted. Still others sheepishly admitted that they had attempted to repair their machines or to remove something while their machines were in operation. Some injuries were the result of human error—a taxi driver lost half a distal phalanx when his hand was caught in his cab door, a nurse lost a similar portion of a finger when it was caught under the lid of a metal ice bin, and a child of six sheared off the tips of two fingers, one on each hand, in the hinges of a folding chair.

Power presses caused more than 28 per cent of the injuries. Various cutting machines, machine-shop equipment, printing presses, and power saws were responsible for further machine-caused injuries. Doors, knives, hand trucks, blocks-and-tackle, and heavy objects falling on the fingers were the sources of other injuries (Fig. 1).

* Read at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 27, 1956.

Most of the patients in our study were from the unskilled group of workers; occasionally there were patients from the semi-skilled group, and rarely from the skilled group. A large proportion of the patients in the unskilled group were immigrants recently arrived from one of our island territories; they spoke little or no English, and their injuries often occurred within the first few days or weeks of their employment. The accidents were often attributable to lack of understanding of the machines they worked on and of the safety devices, or to inattentiveness and distraction. Injuries in the semi-skilled and skilled groups seemed to be more often due to the familiarity which breeds contempt—they were the results of the worker casually adjusting a printing press or removing an object from a machine while it was still in operation.

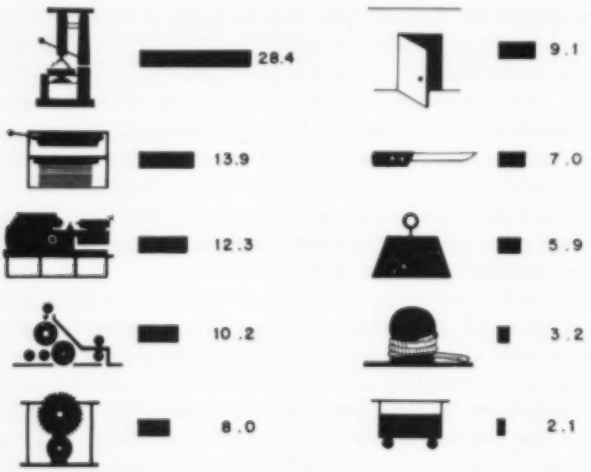

FIG. 1

Man-powered tools and objects caused 27 per cent of the injuries. Slammed doors of cars and buildings accounted for one-third of this total. Most of these injuries were probably preventable.

SURGICAL ASPECTS

As soon as the patient arrived in the emergency room, the injured hand was immersed in a container of saline to which had been added six to eight cubic centimeters of a commercial antibacterial detergent. The action of the detergent helped to remove surface grease, dirt, or ink, and the bits of torn tissue, fat, and clot. During the twenty-minute period of the soak, 1500 units of tetanus antitoxin were administered intramuscularly and a sedative-analgesic medication such as nembutal or demerol was given the patient. The attending surgeon was notified.

In the emergency operating room with the surgeon masked, gloved, and gowned, the injured extremity was prepared and draped. Anaesthesia was obtained by digital nerve block. One and one-half to two cubic centimeters of 1 per cent procaine was injected with a No. 25 needle at the proximal digital crease. If necessary, this was reinforced with a second injection. In multiple finger injuries, the nerves of the individual fingers were blocked successively as they were repaired. In the 220 cases of surgical repair begun under nerve-block anaesthesia, it never was necessary to resort to general anaesthesia. The latter was used in a few cases early in the series and when especially indicated, as in cases of undue psychic disturbance or in very young patients. A tourniquet, either on the arm or the finger, was never used nor was it ever found necessary (Fig. 2).

The general principle of saving as much tissue and length as possible was always followed. In crushing injuries, the aim was to salvage all possible pulp and the nail for

reconstruction of the finger tip rather than to amputate for expedient closure of the wound (Fig. 3).

In traumatic transverse amputations, including the flexor digitorium profundus tendon or the distal joint, the base of the distal phalanx was removed and the condyles of the middle phalanx rongeured off to allow flap closure without tension (Fig. 4). If the proximal third of the distal phalanx remained, including the insertion of the flexor digitorum profundus, only enough bone was removed (usually three to five millimeters) to allow approximation over the bone end of lappets of subcutaneous tissue in order to form a soft base for a graft. The graft was usually of intermediate thickness taken under

FIG. 2

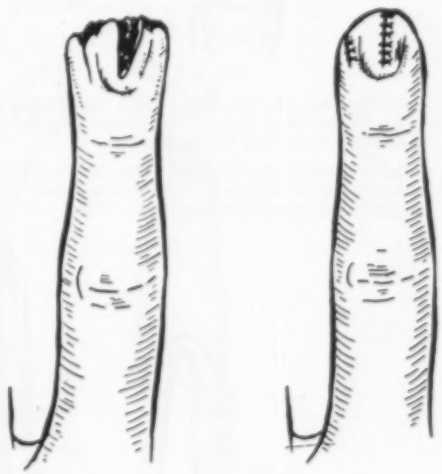

FIG. 3

Fig. 2: One and a half to two cubic centimeters of procaine was injected at the level of the proximal digital crease. A tourniquet was never used.

Fig. 3: Meticulous débridement of severely crushed fingers often resulted in flaps which were utilized to reconstruct a badly damaged distal phalanx.

procaine infiltration from the upper medial aspect of the forearm or from the upper thigh area (Fig. 5). The graft was sutured in place and a stent was tied over it. The entire finger was then encased in a snug, firm pressure dressing made from two four-by-eight inch cotton-filled gauze squares, triply folded and placed one over the other at right angles. The dressing was encased in a spiral finger bandage and reinforced with adhesive tape (Fig. 6). The patient was given a sling to wear and was instructed to keep the hand elevated on pillows when resting at home or while asleep. If there was sharp, long, oblique amputation of the finger tip, including half of the pulp, the matrix, the fingernail, and the tuft, repair with graft only would give an awkward sharp finger tip without adequate pulp. The bone was therefore trimmed to a level just proximal to the proximal end of the defect, leaving the nail matrix, and a flap was fashioned by an incision in the paronychial groove between the nail matrix and the remaining lateral skin of the finger tip. This flap was then sutured over the bone end and to the correspondingly shortened nail matrix. The remaining defect, usually twelve to fifteen millimeters in diameter, was covered with a split-thickness graft (Fig. 7). In a crush injury with multiple flap formation and exposure of the bone, the bone was shortened only enough to allow tensionless reapproximation of the debrided flaps (Fig. 3). In a few cases when the finger tip, including the bone, was almost entirely severed, but with one neurovascular bundle remaining in a narrow bridge of skin, the distal finger portion was replaced and sutured (Fig. 9).

FIG. 4

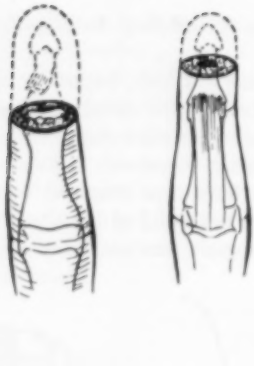

FIG. 5

Fig. 4: When the flexor profundus tendon was divided or the distal joint crushed, the remaining portion of the distal phalanx was excised and the condyles of the middle phalanx were trimmed. Flaps were fashioned to close the stump.

Fig. 5: If the profundus tendon was spared, only enough of the remaining bone was trimmed to allow approximation of lappets of subcutaneous tissue over the bone end to serve as a base for the graft. The "square" end becomes rounded with time.

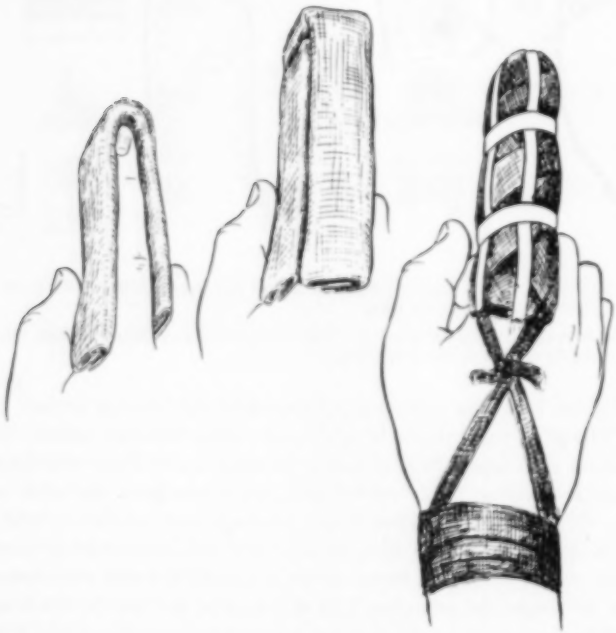

FIG. 6

Triply folded four-by-eight-inch gauze pads were placed at right angles to each other and the pressure applied with roller gauze and adhesive tape. With this dressing, there is singularly little pain, slight maceration of the suture lines or none at all, and no swelling.

During the thorough débridement and the repair, the wound was copiously irrigated with saline. 00000 silk was used for the repair and for application of the grafts; catgut was never used. Antibiotics were not used, and judging from the results obtained the omission of these was not detrimental to successful healing.

When grafting was done, the dressings and sutures remained in place for seven to nine days, and when they were removed a modified less bulky pressure dressing was

FIG. 7

Oblique amputation: the oblique bone end was removed and the lateral skin flap was brought over the bone end and sutured to the nail base which was trimmed straight; the remaining defect was covered with a thick split graft. The pulp was thus reconstituted and the nail spared.

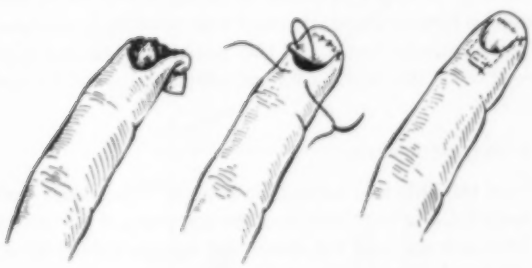

FIG. 8

Fig. 8: After avulsion of the nail and pulp, the finger tip was reconstituted by re-covering the exposed phalangeal tuft with nail-matrix tissue and pulp by the maneuver illustrated. The nail regrew.

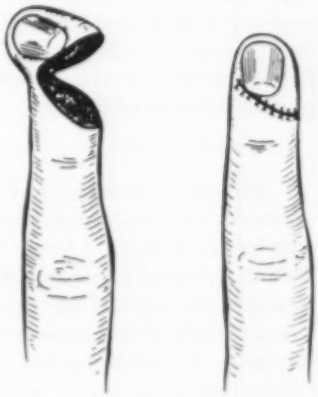

FIG. 9

Fig. 9: With sharp partial amputation, when one vascular bundle remained, salvage was possible. The pressure dressing acted as a splint obviating the need for wire fixation of the bone and the possible compromise of the remaining blood supply.

applied. It was replaced twice weekly or at weekly intervals until complete healing had occurred. In cases of injury caused by crushing, when grafting was not done but considerable swelling or delay in healing was anticipated, the pressure dressings were allowed to remain on for twelve to fourteen days. At this time, there was usually little or no maceration at the suture lines and the fine silk sutures were removed without difficulty.

Distal pedical flaps obtained from the palm or from an adjacent finger were used only three times in the whole series. Two of these were used in sharp thumb amputations when there was dire need to conserve length. The third was used for cosmetic reasons in the child mentioned earlier who lost the tips of two fingers in the hinges of a folding chair.

Immediate postoperative complications were few. There were two infections (0.8 per cent) of sufficient magnitude to require prolonged after-care; fortunately, however, there was no additional loss of tissue. Grafts were lost in two patients because of hematoma formation. There were, of course, many patients in whom small portions of graft were lost or small bits of tissue devitalized by the original injury which were not excised during the débridement; healing was not unduly delayed in these instances. The known late complications included two neuromata which required excision and two amputations which required revision because of scar adherence to bone.

An attempted one-to-five-year follow-up study was not satisfactory; only forty patients returned for re-examination and evaluation. In this group, however, none of the patients had required secondary medical care and none had lost further time from work because of the original injury. Also, none of the patients had found it necessary to change their type of work because of the defects resulting from the injuries. Those with grafted

TABLE I

PATIENT DATA

Injuries	No.	Hospital Days (*Average*)	Office Visits (*Average*)	Days out of Work (*Average*)
Single phalangeal injury	197	0.53	6.0	25.2
Multiple phalangeal injuries	43	0.95	7.0	33.4
Total patients	240	0.61	6.1	26.7

finger tips had no complaints of inability to apply pressure or to hold objects or tools required in their work. Rehabilitation by formal physiotherapy was not found necessary for any patient in this group. The early return to work, and the motivated use and mobilization of the injured hand were found to be the most rapid and effective means for optimum restoration of function.

ECONOMIC ASPECTS

The cost of these injuries had both tangible and intangible aspects. The direct costs, of course, were those related to the hospital, doctors' fees, and the payment of the indemnity for the portion of finger lost. The average cost for these was between $450.00 and $500.00, or a total of about $100,000.00 for the group. These direct costs are covered by the premium payments. There are also, of course, indirect costs which must also be paid for out of the premiums; these cover administration of the insurance fund and profits to the company. A further indirect cost is that of the Workmen's Compensation Board. The tremendous overhead of this organization in administering the relations between the injured worker, the employer, the insurance carrier, and the physician is borne by the taxpayer. It is possible that these indirect costs equal the direct costs. Therefore, this group of injured workers represents a possible loss to the community of approximately $200,000.00, which is paid for by both the consumer of the goods and services and the taxpayer.

Other indirect costs are apparent but cannot be evaluated. The idled machine and the resulting loss of production must certainly be included in these. Intangible as well as indirect is the cost of the psychic trauma to the injured worker, his possible permanent defect and the effect of this on his future employability.

DISCUSSION

The effectiveness of the scheme of management adopted for this type of injury is indicated by the number of days that the patient was hospitalized, the number of office visits required thereafter, and the period of time the injured person lost from work. Only

TABLE II

ANATOMICAL DISTRIBUTION OF INJURIES

	Thumb (*Per cent*)	Index (*Per cent*)	Long (*Per cent*)	Ring (*Per cent*)	Little (*Per cent*)
Right	9.3	14.6	9.3	4.9	6.5
Left	9.8	21.2	12.5	7.0	4.9
Total	19.1	35.8	21.8	11.9	11.4

ninety of the 240 patients in the series were admitted to the Hospital. (The average stay was 1.7 days.) Thus, two-thirds of the patients in the series did not require hospitalization. The patient made an average of six office visits before he was considered ready to work. In many instances, the visits necessary for actual care of the injury were fewer than six, but the additional calls were often for moral support and suasion to effect earlier return to work (Table I).

The average time lost from work was 26.7 calendar days or nineteen to twenty work days. The cumulative figures indicate that 50 per cent of the group returned to work at the end of three and one-half weeks and that 85 per cent returned in six weeks (Chart I).

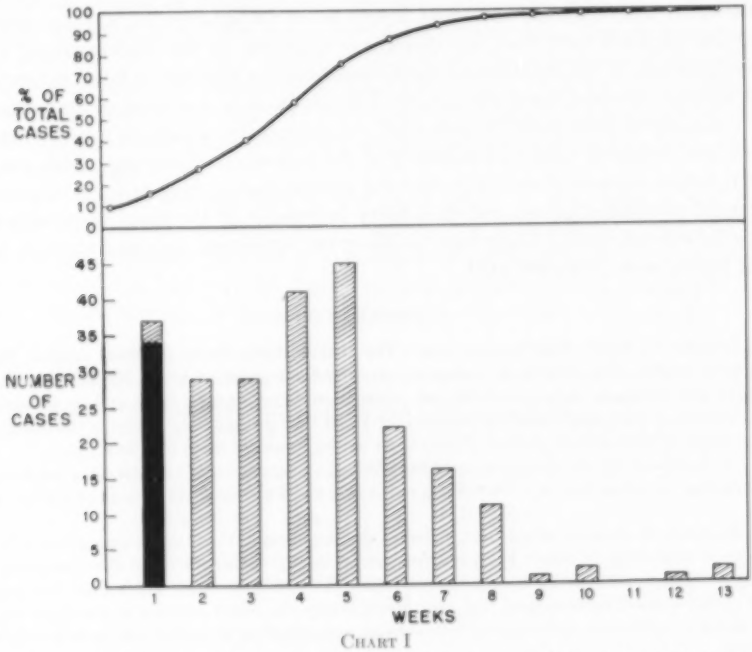

CHART I

Return to work. Thirty-four patients (the dark bar) returned to work within three days. The number returning in the weeks succeeding the injury are indicated by the shaded bars. The top curve indicates the cumulative return to work; 77 per cent of the total number had returned by the end of the fifth week.

Thirty-four patients returned to their jobs within the first three days of injury. Many of these had, or were temporarily given, supervisory jobs; others returned to work in order to continue their high earnings, being unwilling to take the loss of the difference between their wages and the Workmen's Compensation Board payments. The 15 per cent who returned to work after six weeks included patients with multiple finger injuries, the two patients in whom infection had developed, and some older patients with trophic changes and stiffness. There were others who postponed return to work apparently because of fear. Their accidents seemed to have created in them the feeling that their machines represented a threat to their persons and to their livelihoods.

From the technical surgical point of view the treatment of these patients on an ambulatory basis proved practicable and satisfactory. At first there was hesitation about modifying or eliminating some of the well established methods of doing hand surgery — hospital admission, the use of a major operating room, general anaesthesia, tourniquet, and antibiotics. However, as time went on, the accumulating results indicated that the simplified scheme of treatment could be safely followed. In what were essentially small

wounds in areas with excellent blood supply, the omission of antibiotics did not seem an undue risk. The fact that only two major infections occurred in our series seems to justify this course. The avoidance of general anaesthesia undoubtedly reduced postoperative complications and morbidity, as well as hospitalization costs. It is estimated that the patients treated on an ambulatory basis represented a saving in hospitalization costs of about $10,000.00. Also, the fact that the patient was not admitted to the hospital decreased the magnitude of his injury in his own mind, thereby minimizing his psychic trauma and accelerating his return to work.

SUMMARY

The social and economic factors of injury to, or amputation of, a distal phalanx in a series of 240 patients have been discussed and analyzed. It was demonstrated that judicious modification of the established rigid conditions for reparative hand surgery may be applied without compromising the results. The adoption of a scheme of ambulatory management simplified postoperative care and was eminently satisfactory in the early rehabilitation and return to work of a majority of the patients in the group which was studied. The ambulatory system of care also effected substantial savings in hospitalization costs. The surgical principles for reparative surgery in trauma of the hand were reiterated and methods for reconstructing finger tips, utilizing the remaining pulp and the nail, in various types of injury were demonstrated.

DISCUSSION

Dr. Darrel T. Shaw, Cleveland, Ohio: The authors have shown practical surgical judgment in adapting good surgical principles to an emergency-room and out-patient routine. By their system they have been able to give adequate early care to injured patients on an out-patient basis, and by encouraging early return to work they have minimized the emotional trauma that accompanies injury to the hand. An important by-product of the authors' system of care is an earlier return of hand function.

We are impressed by the economic pressure which the average worker suffers when he is injured. We must do our best to return him as a functioning unit to his social and economic sphere as quickly as possible.

Dr. Raymond M. Curtis, Baltimore, Maryland: Since hospital beds are at a premium, it is important that we know what type of minor hand injuries can be treated satisfactorily in the emergency operating room and thereafter cared for on an out-patient basis. The excellent results which these two authors have obtained in this series of cases suggest that this type of injury, the minor avulsion at the finger tip, can be so treated, and if a meticulous technique of débridement and cleansing is carried out, satisfactory results can be expected.

Although the authors did not use antibiotics in this group of patients, I personally prefer to continue their use, particularly in patients with compound fractures or wounds at the site of a joint. Also, I prefer the use of a tourniquet in the repair of these injuries.

In the series of cases presented, it was necessary in only two instances to use a cross-finger pedicle flap for coverage at the tip of the injured fingers. The cross-finger pedicle flap is an excellent procedure, but before subjecting a normal finger to surgery to obtain the flap for grafting, one must be certain that the condition warrants it. In some instances, residual stiffness in a previously normal finger may follow taking skin from it for a cross-finger flap.

Careful attention must be given to the volar digital nerves when they have been divided in the avulsion or amputation, for if the terminal portion of the nerve is allowed to remain at the tip of the finger and become involved in scar tissue as the neuroma forms, varying amounts of disability will follow. If the cut end of the digital nerve is allowed to retract back into normal subcutaneous tissue following a resection of a portion of the nerve, there will be less chance of disability.

Osteogenic Sarcoma in the Hand *

BY ROBERT E. CARROLL, M.D., NEW YORK, N. Y.

From the Bone Tumor Service, Memorial Center for Cancer and Allied Diseases, and New York Orthopaedic Hospital, Columbia-Presbyterian Medical Center, New York

A malignant tumor of the hand is a rare occurrence. The most common malignant condition of the hand is squamous-cell carcinoma of the skin. The skeletal structures are rarely involved by a primary neoplasm. Therefore, the experience of one surgeon or of one clinic is usually not sufficiently broad to serve as a basis for the treatment of a primary skeletal tumor of the hand. In the course of treating osteogenic sarcoma in general, the author was immediately aware of a marked difference in the prognosis and course of such a tumor in the hand.

Ten cases of osteogenic sarcoma in the hand are presented here. When possible, the specimen was studied histologically by outstanding pathologists in order to be sure of the proper identification. In Case 4, a question of myositis ossificans was raised; the pathologists would not, however, be shaken in their identification of osteogenic sarcoma. No cases of chondrosarcoma or fibrosarcoma have been included in this study.

TABLE I

LOCATION OF OSTEOGENIC SARCOMA IN THE HAND

Digits:	I	II	III	IV	V	Total
Distal phalanx	Case 5 Case 8	Case 1				3
Proximal phalanx					Case 4	1
Metacarpal	Case 3	Case 7 Case 10		Case 2	Case 9	5
No location given	Case 6					1

One case [10] had been carried in the literature for many years as a case of osteogenic sarcoma. Through the kindness of the surgeon, the material was reviewed by several pathologists independently, and the unanimous conclusion was that the correct diagnosis was synovioma.

Statistics in such a small number of cases are of little significance; no attempt, therefore, is made to state percentages. It will be seen that all ages and both sexes are represented about equally. One hand is not more frequently involved than the other. There is about equal division between metacarpals and phalanges (Table I). The clinical history of osteogenic sarcoma developing in the hand is not markedly different from that of this neoplasm elsewhere in the body, usually one of pain and swelling. In the hand, the swelling is usually seen long before pain begins. As far as can be determined, trauma plays no part in the etiology of osteogenic sarcoma in the hand. This is of particular interest when one remembers how frequently the hand is subjected to trauma.

* Read at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 27, 1956.

PRIMARY SITE TUMORS

Six tumors reported in the literature appear to have had no complicating factors in their development other than involvement of the bone itself. These are briefly reviewed:

Case 1. Clark reported a tumor arising in the distal phalanx of a colored woman, thirty-seven years old. One year before there had been some trauma to this area. Gradual swelling with persisting pain in a digit, which showed roentgenographically both proliferative and destructive changes, led to biopsy. After study of the specimen, osteogenic sarcoma was diagnosed, and the ray was amputated. The patient was well and free of disease two and one-half years after operation. More recent information (furnished by Dr. R. Warner Wood) reports that the patient is alive and well today. She is daily using her hand in the performance of her work. This increases the time of survival to six and one-half years.

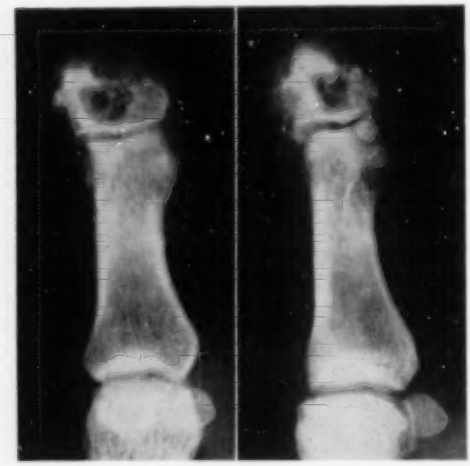

Fig. 1

Anteroposterior and oblique roentgenograms of the terminal phalanx of the thumb, showing the tumor. (Reproduced by permission of J. P. Lippincott Company from "Osteogenic Sarcoma of Phalanx after Chronic Roentgen-Ray Irradiation" by Robert E. Carroll, John T. Godwin, and William L. Watson. Cancer, **9**: 753, 1956.)

Case 2. Clifford and Kelly briefly reported a case of osteogenic sarcoma arising in the fourth metacarpal. Amputation of the fourth and fifth rays was performed. The patient lived at least seven years after the operation with no evidence of recurrent disease.

Case 3. Coley and Higinbotham reported the case of P. S., a nineteen-year-old boy who had a tumor of the metacarpal of the right thumb. On two occasions, attempts had been made to excise this tumor. After the second recurrence radiation therapy was prescribed. Lung shadows were interpreted as metastatic tumor fourteen months after initial excision. However, the patient was alive and well when lost to follow-up two years later.

Case 4. Coley and Higinbotham also reported the case of W. C., a thirty-year-old man who had a tumor in the proximal phalanx of the fifth digit of the right hand. There had been several episodes of trauma, including fractures, to that hand on previous occasions. After a relatively slight blow in 1936, a gradually increasing swelling and pain of an aching nature were noticed in the web space between the fourth and fifth digits. Amputation was carried out in February 1937, through the base of the fourth and fifth metacarpals. The pathologist reported osteogenic sarcoma arising from the proximal phalanx of the fifth digit. The operation left a functional hand, and the patient obtained employment as a bus driver. He was last seen in 1948, and was found to be healthy with no evidence of local recurrence or metastasis. This man was known to be free of disease for eleven years after partial resection of the hand.

Case 5. D'Antona, in 1934, reported the case of a housewife, eighty-five years old, who had noticed persisting pain and slowly progressive swelling in the distal phalanx of the left thumb for eighteen months prior to examination. Upon examination, a firm swelling the size of a walnut was found on the distal phalanx.

Fig. 2: Photomicrograph of the skin overlying the tumor, showing severe hyperkeratosis (hematoxylin and eosin, × 140). (Reproduced by permission of J. P. Lippincott Company from "Osteogenic Sarcoma of Phalanx after Chronic Roentgen-Ray Irradiation" by Robert E. Carroll, John T. Godwin, and William L. Watson. Cancer, **9**: 754, 1956.)

Fig. 3: Photomicrograph of subcutaneous tissue demonstrating scarring and atrophic sweat glands (hematoxylin and eosin, × 140). (Reproduced by permission of J. P. Lippincott Company from "Osteogenic Sarcoma of Phalanx after Chronic Roentgen-Ray Irradiation" by Robert E. Carroll, John T. Godwin, and William L. Watson. Cancer, **9**: 754, 1956.)

Fig. 4: Photomicrograph of section of the neoplasm showing osteoid and bone formation (hematoxylin and eosin, × 140.) (Reproduced by permission of J. P. Lippincott Company from "Osteogenic Sarcoma of Phalanx after Chronic Roentgen-Ray Irradiation" by Robert E. Carroll, John T. Godwin, and William L. Watson. Cancer, **9**: 754, 1956.)

Fig. 5: Photomicrograph of section of a more anaplastic area of the neoplasm (hematoxylin and eosin, × 310). (Reproduced by permission of J. P. Lippincott Company from "Osteogenic Sarcoma of Phalanx after Chronic Roentgen-Ray Irradiation" by Robert E. Carroll, John T. Godwin, and William L. Watson. Cancer, **9**: 754, 1956.)

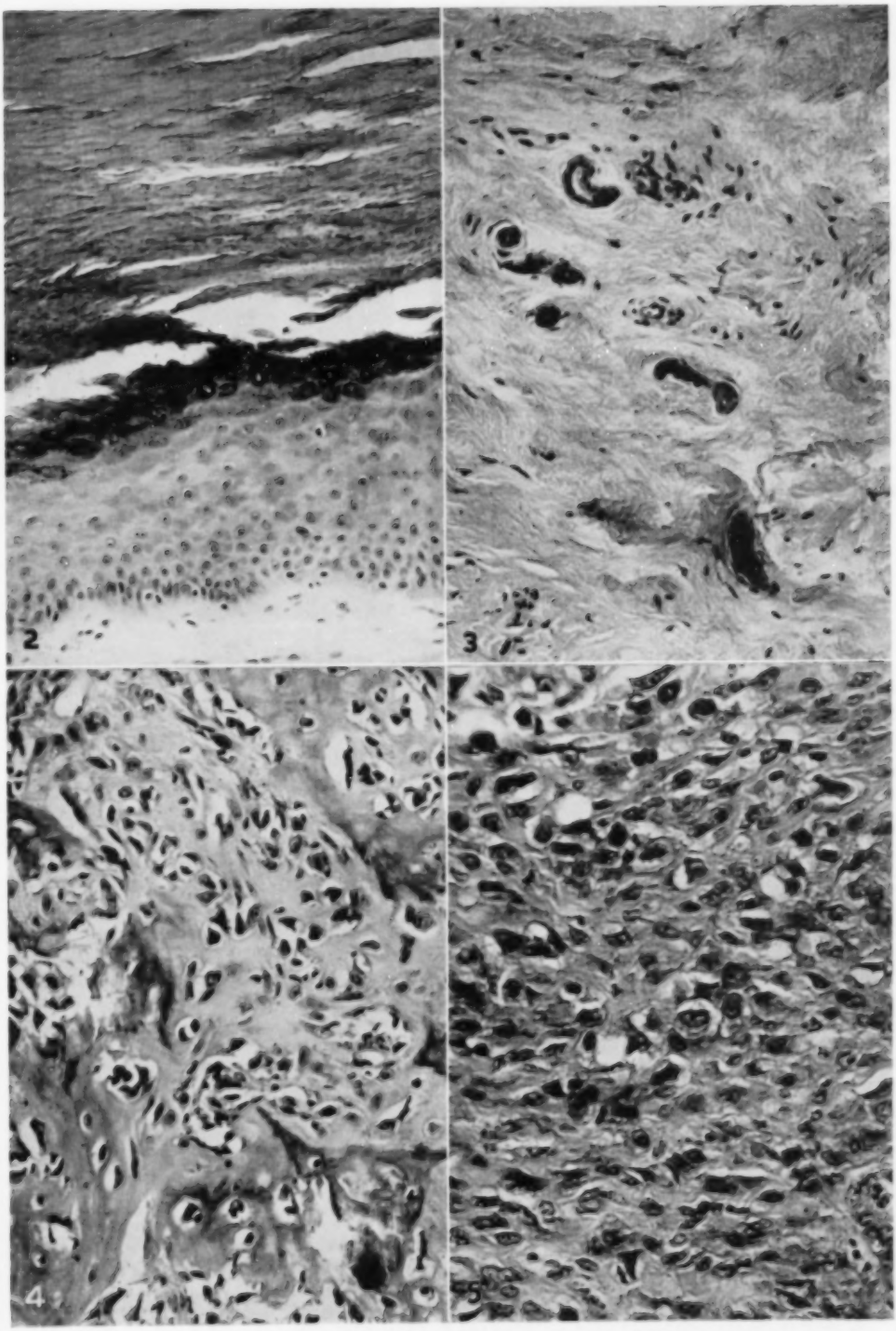

FIG. 4

FIG. 5

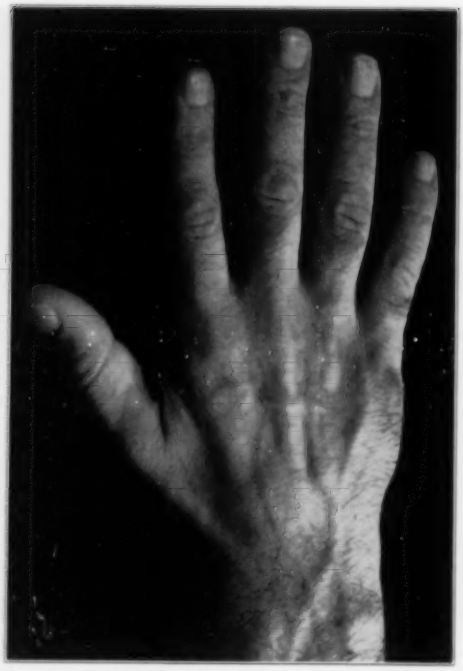

FIG. 6-A

FIG. 6-B

Dorsal and lateral photographs of the right hand (Case 9) when persisting pain called attention to the swelling in the fifth metacarpal. The lateral photograph shows the loss of ability to extend the digit completely.

The roentgenogram showed bone destruction with osseous proliferation. The thumb was amputated at the metacarpophalangeal joint. The pathological diagnosis was osteogenic sarcoma. No further information on this patient is available.

CASE 6. Geschickter and Copeland listed a nineteen-year-old boy who had pain and swelling in his hand of four months' duration. Amputation, in conjunction with x-irradiation, was carried out. The tumor was diagnosed as osteogenic sarcoma. The patient was alive and well ten years after the operation.

From these case histories it seems apparent that a carefully performed local resection as initial treatment offers both good prognosis and a functional extremity. Recent reports indicate that the length of survival may be longer than presently known, since many patients are lost to follow-up (Table II).

IRRADIATION-PRODUCED TUMORS

Although osteogenic sarcoma in the hand is rare, it is of interest to record tumors induced by ionizing radiation. In one patient the radioactive material was injected into the body tissue at a distant site. In the other patient the tumor was produced by the direct exposure of the digit to the penetrating rays of an x-ray machine. However, in both patients, a considerable period of time elapsed before the final change.

CASE 7. Aub, Evans, Hempelmann, and Martland, in a review of the effects of radioactive material administered as medical treatment, reported the case of M. B., a woman, thirty-six years old, who had been given five or more injections of radium salts for arthritis in 1924. The patient was well until 1948, except for short episodes of low-back pain. At that time, the right hand became swollen and painful after a minor blow. Biopsy was done in October 1949, but no definite diagnosis could be made. By September 1950, the tumor of the metacarpal bone had grown so rapidly that resection of the index ray was done. The tumor proved to be osteogenic sarcoma. The general condition of the patient deteriorated and other skeletal

neoplasms developed. The patient died in July 1952, still demonstrating a surprisingly high measurable amount of radium in her tissues.

CASE 8. Carroll, Godwin, and Watson reported an osteogenic sarcoma in the terminal phalanx of the right thumb of a sixty-year-old dentist who had formed the habit of holding his own dental film plates while the x-ray exposure was made. Recurrent skin lesions during the preceding seven years had been called keratosis. The destructive change in the phalanx necessitated amputation through the middle of the proximal phalanx of the thumb. The lesion was found to be an osteogenic sarcoma. Operation gave a functional thumb, and the dentist continued his practice until death from coronary occlusion seven months later (Figs. 1 through 5).

More recently the field of use of radioactive substances has widened considerably. Perhaps these case histories will serve to recall the danger of chronic exposure to intermittent radiation. As the functional tool of the mind, the hand has the greatest risk of overexposure to radiation.

FIG. 7

A roentgenogram of the fifth metacarpal of the right hand (Case 9) showed destructive lesion of the bone. Proliferative osteoblastic, as well as irregular osteolytic changes, were found. These abnormalities were diagnostic of ostegenic sarcoma.

MULTIFOCAL TUMORS

When osteogenic sarcoma develops in many bones in the body, it brings up the question of metastasis from a single primary tumor or from multicentric tumors arising from a skeleton with altered metabolism. When the metabolism of bone undergoes the change of osteitis deformans described by Sir James Paget, the appearance of osteogenic sarcoma is not unusual. If tumors arise in several bones, it is thought to be due to the alteration in the fundamental bone metabolism. The history of one patient is presented to amplify this point.

CASE 9. M. C., a man, thirty-eight years old, had signs of cord pressure. Roentgenographic skeletal survey demonstrated changes in the spine, pelvis, and femora which were compatible with osteitis deformans. The compression of the cord was relieved by laminectomy in July 1949. Bone sections confirmed the diagnosis of Paget's disease. In July 1952, osteogenic sarcoma was found in the humerus and skull. During the next few months, many other bones showed evidence of sarcomatous degeneration. Of particular interest was the development of an osteogenic sarcoma in the fifth metacarpal of the right hand (Figs. 6-A, 6-B, and 7). Death from widespread disease occurred in October 1952.

Should osteogenic sarcoma arise in several bones of the body without evidence of lung metastases, the altered bone metabolism of osteitis deformans is usually found to exist. In general, a patient with osteogenic sarcoma of bone will reveal metastases in his lungs at some future date. It is indeed rare that new foci of metastatic osteogenic sarcoma will be found in other locations before the patient dies. Such cases, however, do exist. Although the metastases from osteogenic sarcoma have been observed in other bones, we are not aware that the hand has ever been so affected.

CASE 10 (Courtesy of Dr. Joseph H. Farrow). W. P., a boy, eighteen years old, had pain and swelling in the distal portion of the left femur over a period of three months. On roentgenographic examination, a destructive process was found to involve the distal portion of the left femur. A biopsy specimen was reported

TABLE II

YEARS OF LIFE FOLLOWING AMPUTATION AS PRIMARY TREATMENT OF OSTEOGENIC SARCOMA

Author	Phalanx of Digit	Metacarpal	At Time Reported in Literature	Subsequent Course
1. Clark	II		2 yrs., 6 mos.	Alive and well, Jan. 1956, adding 4 more years of survival.
2. Clifford and Kelly		IV	7 yrs.	Lost to further follow-up.
3. Coley and Higinbotham		I	2 yrs., 9 mos.	Lung shadow called metastasis in Jan., 1925. Alive and well when lost to follow-up, June 1927.
4. Coley and Higinbotham	V		1 yr., 11 mos.	Free of disease and working when lost to follow-up 11 years after operation.
5. D'Antona	I		Unknown	
6. Geschickter and Copeland	?	?	10 yrs.	Lost to further follow-up.
7. Aub and associates		II	2 yrs.	Died from existing generalized disease.
8. Carroll and associates	I		7 mos.	Death from coronary occlusion.
9. Case M.C.		V	10 days	Died with widespread disease.*
10. Case W.P.		II	4 mos.	Died with multiple metastatic foci.*

* No resection performed on hand.

to be osteogenic sarcoma and the limb was amputated in October 1943. By January 1945, pulmonary metastases were found. Other sarcomata were demonstrated in the skull and ribs. In March 1945, pain and swelling developed in the left hand. Roentgenograms demonstrated sarcomatous change in the second metacarpal bone. No operation was performed on the hand. The patient died in July 1945.

DISCUSSION

When osteogenic sarcoma is included in the differential diagnosis of a hand tumor, the rarity of its occurrence should be appreciated. However, there should be an awareness that it does exist. The progress in the development is the same as in an osteogenic sarcoma of any bone. Once an abnormal structure is found on examination, roentgenograms and biopsy are mandatory.

Although the number of known primary osteogenic sarcomata arising in the hand is small, the prognosis of survival is greater than the figures of 10 to 20 per cent survival at five years set forth in the literature for osteogenic sarcoma in general. Moreover, local resection can be carried out as initial treatment with greater safety than in tumors located at more proximal sites. With a rather favorable prognosis, this also leaves a functional unit. This observation has been expressed by von Matolcsy and Coley, as well as by other observers. When previous surgical attempts have been made, the prognosis for local resection is less favorable.

Should one encounter an osteogenic sarcoma produced by irradiation, the principles

followed in the treatment of a primary tumor are an excellent guide. We shall probably not see patients with radium introduced into the system in the course of therapy. The chances, however, of finding a thumb or finger which has had prolonged exposure to irradiation forces are still great.

If the tumor in the hand develops as a metastatic lesion or arises on abnormal bone as in osteitis deformans, the prognosis is less favorable. The proper care for such a problem will evolve upon steps necessary for the comfort of the patient.

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DISCUSSION

Dowel Intervertebral-Body Fusion

(Continued from page 292)

Dr. Wiltberger has explored extensively the feasibility of doing it better and he is to be commended for it. The next step is the insertion of sufficient additional fixation in the posterior elements so that stability will be maintained while consolidation occurs in order to permit the fusion to take place in a sufficiently large percentage of cases to justify the procedure.

The vertebral interbody technique should be learned by personal observation. There is no need for every surgeon to repeat the mistakes of those who initiate these techniques. Only experienced spine surgeons who have better than average manual dexterity and proper respect for the risks involved should attempt vertebral-interbody fusion.

Reaction of the Epiphysis to Partial Surgical Resection*†

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The study of bone growth has claimed the attention of investigators since the inception of experimental physiology, and the subject continues to stimulate research. Experiments have shown that total skeletal growth can be influenced by dietary and endocrinological factors, and that the growth of a single epiphysis can be altered by local changes. Observations continue to be made on methods of epiphyseal stimulation, epiphyseal transfer, and epiphyseal retardation by stapling.

This report is concerned with the response of growing bone to the loss of a portion of the epiphysis. Studies in which the entire epiphysis was removed were described by Selye who reported growth of a complete new functional epiphysis in twelve to fifteen-day-old rats. This new epiphyseal structure was thought to have developed from the surrounding undifferentiated tissue. However, this potential was found to be confined to very young animals, for when the experiment was repeated in older animals new epiphyseal growth did not occur. A similar experiment was made by Hellstadius, who removed the distal portion of the ulna in two-month-old rabbits, the resected segments including the epiphysis and epiphyseal plate. In the rabbits, a new epiphysis developed and some growth increment at the distal portion of the ulna occurred. In some of the rabbits, the metaphysis was curretted in addition to resection of the epiphysis. A new epiphysis did not develop in these animals, but limited linear growth continued in the distal portion of the ulna.

Experimental destruction of part of the epiphyseal plate was reported by Langenskiöld. In this study, roentgen rays, controlled by a minute aperture, created foci of destruction in selected areas of the growth cartilage. Small central areas of destruction were replaced by an ingrowth of cartilage cells from the undamaged adjacent cartilage and no deformities resulted. Larger areas of central destruction, and even small areas of peripheral destruction, caused deformity. Ford and Key reported a study of experimental trauma to different areas of the epiphyseal cartilage, produced by drilling this structure. Their results also showed that small central cartilaginous areas could be destroyed with no consequent deformity or interference in growth, while peripheral damage caused extensive changes.

The purpose of the experiments described in this report was to study the changes that occur in the epiphysis following partial resection of the epiphyseal cartilage. Observations were made of the response of the remaining cartilage to partial resection, and of the regeneration of functional growth cartilage in order to determine a method of preventing deformities. In each experiment, six-week-old rabbits were used. They were anaesthetized by intraperitoneal injection of sodium pentobarbital. After routine preoperative skin preparation, the lateral condyle of the distal portion of the femur was exposed and the lateral epiphyseal line visualized before resection. After closure of the wound, each animal received procaine penicillin daily for three days.

PARTIAL RESECTION OF THE EPIPHYSEAL CARTILAGE

Thirty-three rabbits were used in an experiment to determine the effect on growing bone of the surgical removal of a segment of its epiphyseal cartilage. The cartilaginous plate of the lateral condyle of the femur in the rabbits was exposed on its lateral aspect,

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† Read at the Forum on Fundamental Surgical Problems of the Fortieth Clinical Congress of the American College of Surgeons, Atlantic City, New Jersey, November 17, 1954.

TABLE I

VALGUS DEFORMITY AND SHORTENING FOLLOWING PARTIAL EPIPHYSEAL RESECTION

With Bone Wax			Without Bone Wax		
Days After Resection	Valgus Factor (*Centimeters*)	Shortening (*Centimeters*)	Days After Resection	Valgus Factor (*Centimeters*)	Shortening (*Centimeters*)
9	0	0	13	0	0
14	.05	0	18	.05	.10
21	.05	.10	28	.17	0
22	.05	.10	30	.30	.05
24	0	.10	33	.23	.27
28	.06	0	36	.40	.10
28	.10	.10	42	.15	.15
35	.05	0	42	.20	.18
35	.10	.05	56	.24	.15
38	.15	.05	60	.20	.18
42	0	.10	63	.13	.37
49	.30	.10	63	.24	.72
55	.10	.05	63	.15	.40
57	.05	.15	66	.32	.73
86	.30	.22	66	.50	.45
86	.35	.10	90	.60	.65
90	.35	.45			

The mean valgus factor of animals measured thirty or more days after resection with bone wax is .18 centimeter ($\sigma = \pm$ .14 centimeter); without bone wax, .24 centimeter ($\sigma = \pm$ .15 centimeter).

The mean shortening in this group with bone wax is .13 centimeter ($\sigma = \pm$ .13 centimeter); without bone wax, .30 centimeter ($\sigma = \pm$ .24 centimeter).

and one-half of the plate subserving this condyle was removed by curettement. The adjacent bone of the epiphysis and the metaphysis was also removed so that the resulting defect resembled a shallow pit in the lateral condyle with the epiphyseal line seen in its base. In an effort to prevent rapid filling of the defect by reactive bone tissue, bone wax was firmly packed into the resected area in seventeen of the animals. These rabbits were sacrificed at intervals between nine and ninety days after operation. The femora which had been operated upon and the opposite control femora were removed and dissected free of soft tissue. Measurements were made of shortening and deformity. After roentgenograms were made, each distal portion of the femur was sectioned in the coronal plane. Each such portion of the femur was divided into anterior, middle, and posterior thirds. Sections were cut from these areas and were stained with hematoxylin and eosin.

Measurements were made with a sliding caliper. Shortening was determined by measurements from the femoral head to the distal medial condyle. The degree of valgus was expressed as the valgus factor, and represented the difference between the distance from the femoral head to the medial and lateral condyles after correction for the normal difference between these points as measured on the control side. In some animals this factor was as high as .60 centimeter.

The operative specimens showed a valgus deformity but this was not proportional to the age of the sacrificed animal. In the animals with bone wax in the defect, there was a slight tendency for less valgus to develop, but no significant conclusions could be drawn. The mean valgus factor of ten animals with bone wax examined after thirty days or more postoperatively was .18 centimeter. Thirteen comparable animals in which bone wax was not used showed a valgus factor of .24 centimeter. Femoral shortening was greatest in those animals with severe valgus.

FIG. 1

Twenty-one days following resection of part of the lateral epiphyseal plate, and packing the defect with bone wax. The valgus factor is .05 centimeter. The epiphyseal line is unchanged to the point of resection where it is in contact with the bone wax. No fusion is seen in this section.

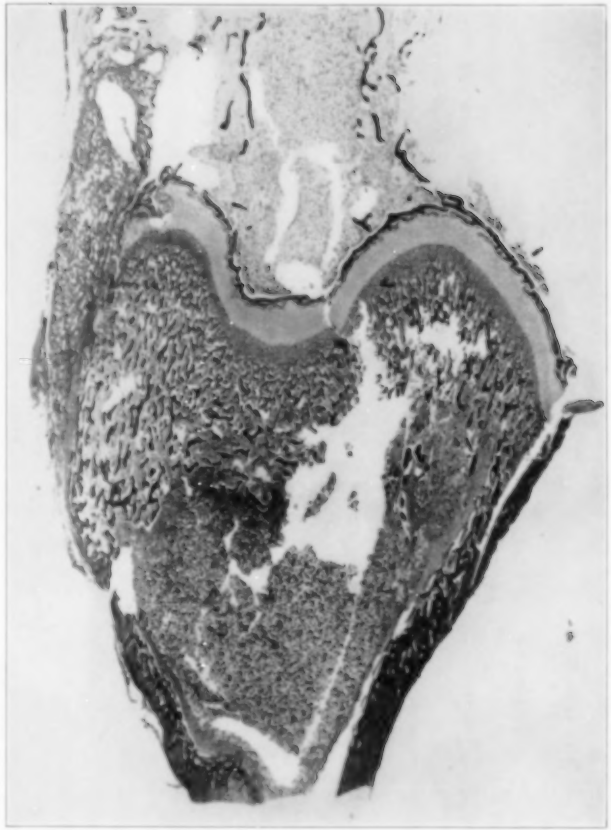

FIG. 2

Thirty-five days following resection of part of the lateral epiphyseal plate and packing the defect with bone wax. The valgus factor is .05 centimeter. The epiphyseal plate shows normal growth characteristics to the point of resection where it is in close contact with the bone wax.

FIG. 3

Thirteen days following resection of the lateral epiphyseal cartilage in which no interposing material was used. No valgus has developed, but fusion between the epiphysis and metaphysis is already present.

FIG. 4

Forty-two days following resection of part of lateral epiphyseal plate. The valgus factor is .20 centimeter. The remaining lateral epiphyseal plate is not producing growth, and a broad area of dense bone is uniting the epiphysis to the metaphysis. This response to surgery usually causes marked valgus.

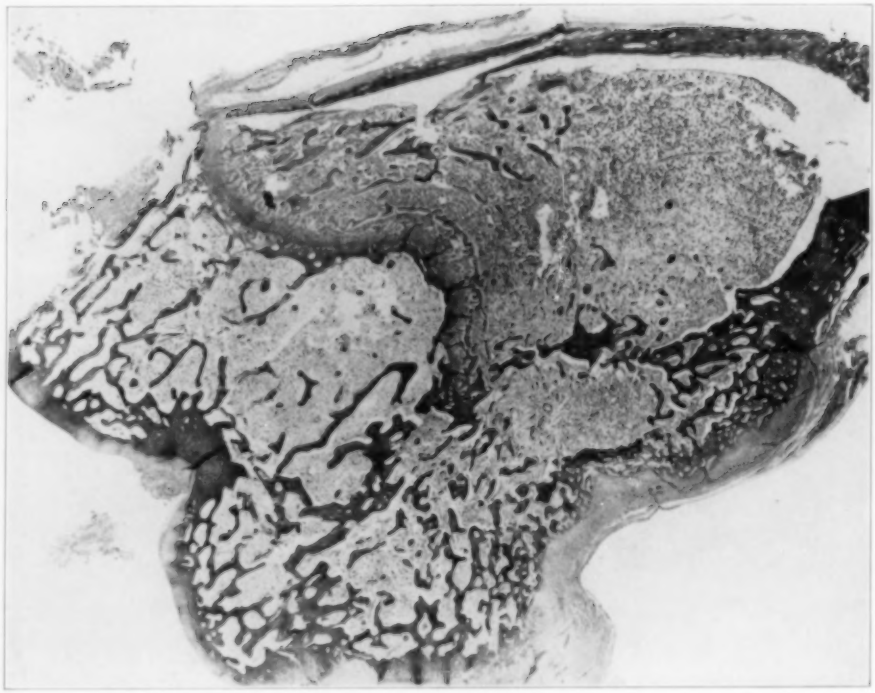

FIG. 6

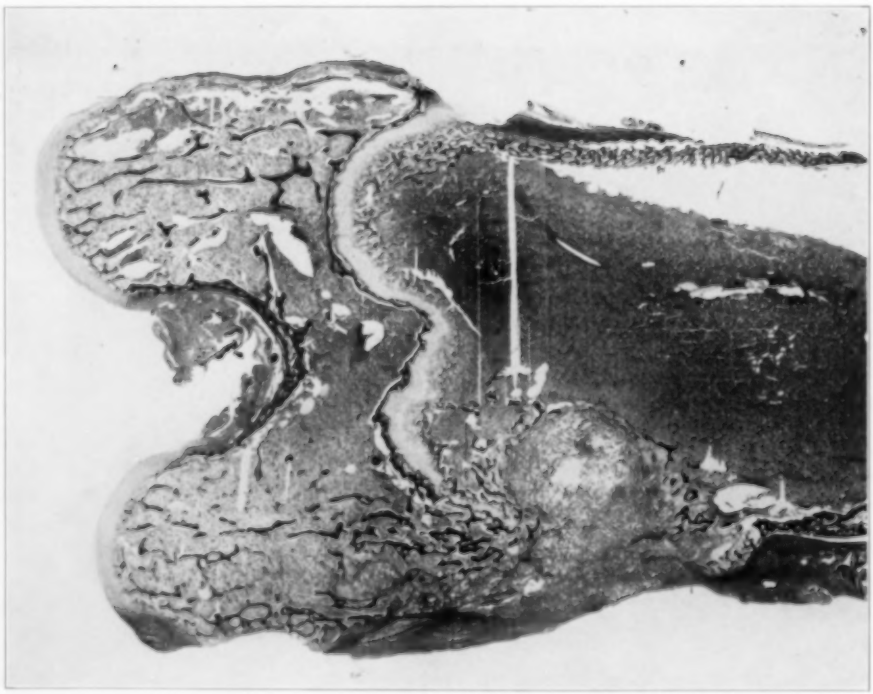

FIG. 5

FIG. 7

Twenty-eight days following resection of the lateral epiphyseal plate. The valgus factor is .17 centimeter. The lateral epiphyseal plate is displaced and atrophic. Part of the resected area is filled with a new fibrocartilage mass which is extending through the bone scar toward the epiphyseal line.

Histological study revealed the epiphyseal plate of the medial condyle to be unaffected by the surgery done on the lateral segment, and showed normal cartilage maturation and enchondral osteogenesis continuing despite abnormalities in the lateral portions of the cartilage. The central or intercondylar segment of cartilage showed continued normal growth sequences except in those in which the lateral changes were very extensive.

The remaining portion of the epiphyseal plate traversing the lateral condyle showed two types of response. In some cases, chondrogenesis, maturation, and hypertrophy with normal columnar arrangement of cartilage and bone growth occurred to the very point of resection. Here a thin line of bone trabeculae bridged the epiphyseal line fusing the epiphysis to the metaphysis. This bridge was anchored on the epiphyseal side to the terminal bone plate of the epiphysis while its metaphyseal anchor was united to the bone columns formed from the lateral epiphyseal line. Such specimens frequently showed a

Fig. 5: Thirty-eight days following resection of the lateral part of epiphyseal cartilage and packing the defect with bone wax. The valgus factor is .15 centimeter. The remaining cartilage adjacent to the area of resection is atrophic and is surrounded by reactive bone. An area of fusion of the epiphysis and the metaphysis is present between the end of the cartilage line and the bone wax.

Fig. 6: Forty-two days following resection of part of the epiphyseal plate. The valgus factor is .15 centimeter. The epiphyseal plate was widely resected and firm fusion has developed. The remaining cartilage of the lateral condyle shows no growth characteristics.

TABLE II

VALGUS DEFORMITY AND SHORTENING FOLLOWING PARTIAL RESECTION OF THE EPIPHYSEAL CARTILAGE WITH FILLING OF THE DEFECT WITH METHYL METHACRYLATE

Resection with Methacrylate			Controls (Resection without Methacrylate)		
Days Postoperative	Valgus Factor (*Centimeters*)	Shortening (*Centimeters*)	Days Postoperative	Valgus Factor (*Centimeters*)	Shortening (*Centimeters*)
25	.10	.05	25	.17	0
43	.23	.23	33	.23	.27
43	.36	.50	42	.15	.15
48	.31	.30	45	.20	.18
50	.36	.35	50	.20	.17
50	.20	.25	56	.24	.15
50	.23	.32	60	.13	.37
64	.26	.30	63	.27	.50
64	.20	.16	65	.15	.40
64	.10	.12	65	.24	.62
65	.22	.26			
65	.26	.35			
65	.22	.32			
m = .23 centimeter $\sigma = \pm$ .08 centimeter		m = .27 centimeter $\sigma = \pm$ .11 centimeter	m = .20 centimeter $\sigma = \pm$ .05 centimeter		m = .28 centimeter $\sigma = \pm$ .16 centimeter

new, inwardly displaced lateral cortex, narrowed in diameter and corresponding to the abbreviated epiphyseal line. The conversion of the pit-shaped resected area into an elongated longitudinal defect was also seen, and this was evidence that some growth had occurred in the lateral condyle subsequent to surgery, despite microscopic and roentgenographic evidence of a thin layer of bone fusing the epiphysis to the metaphysis. This type of response to resection usually occurred when resection was limited, and did not fully extend to the mid-point of the lateral condyle. Also, it occurred when bone wax was used. Sections from the femora of ten animals which showed preservation of one-half or more of the cartilage of the lateral condyle and in which bone wax had been used, demonstrated the mean valgus factor of .10 centimeter. The remainder of the group showed a valgus factor of .31 centimeter.

In those animals in which the curettement of the lateral condyle, as shown by roentgenograms and by microscopic examination of sections, reached as deep as the mid-point of the condyle, a more profound disturbance of growth resulted. The epiphyseal cartilaginous plate in the intercondylar area was thinned, and cartilage maturation and bone growth was irregular and retarded. The remaining cartilage of the lateral condyle was also thinned, and showed only isolated nests of growth characteristics as it traversed areas of well developed reactive bone to the point of resection where a broad zone of bone sealed the epiphysis to the metaphysis. Displaced islands of cartilage, some of which showed growth sequences, were scattered throughout the condyle. The animals in which these conditions existed showed severe valgus deformity and shortening of the femur.

One of the objectives of this study was to determine if regeneration of epiphyseal cartilage occurred in growing animals. These experiments produced no evidence of cartilage regeneration manifesting enchondral growth. Large chondromatous areas were frequently noted in the field of surgery, but no linear organization, chondrocyte hypertrophy, or vascular invasion characteristic of enchondral growth were seen.

PARTIAL RESECTION OF THE EPIPHYSEAL CARTILAGE, FILLING THE DEFECT WITH METHYL METHACRYLATE

Methyl methacrylate has been found to cause a minimum of fibrosis and bone reaction in living tissue, and this material in the monomeric form was used to fill the surgical defect of the lateral condyle instead of the wax used in the preceding experiment. Methyl methacrylate is a powder which hardens within five minutes after the solvent is added, and in the process of hardening, heat is released. The effect of this exothermic reaction on the tissues was minimized by allowing the substance to attain a putty-like consistency before placing it into the bone defect.

This experiment was carried to a conclusion in twenty-three six-week-old rabbits, the methods described in the foregoing experiment being used. The methacrylate was used in thirteen animals, the remaining ten serving as controls. The animals were sacrificed at intervals of twenty-five to sixty-five days following surgery. The mean valgus factor of the animals in which methacrylate was used was .23 centimeter. Histological studies were comparable with those of the former experiment. The use of methyl methacrylate instead of bone wax had no effect in decreasing deformity.

EPIPHYSEODESIS FOLLOWED BY RESECTION

In twenty-two animals a study was conducted simulating the clinical condition of fusion across part of the epiphyseal cartilage which is occasionally encountered in children following epiphyseal injuries. In six-week-old animals, the lateral epiphyseal plate of the distal portion of the femur was exposed and a rectangular segment of the perichondrum and the underlying bone crossing the epiphyseal cartilage was removed and reversed, after the underlying cartilage had been curetted to a depth of two to four millimeters, according to the technique of Phemister. Thirty days later, roentgenograms were made and the operative area was again exposed. In sixteen animals, fusion was seen roentgenographically and a bridge of bone was observed at surgery. In ten of the animals, the fusion area was widely resected and sufficient bone was curetted in order to clearly visualize the epiphyseal plate. The surgical defect was then packed with bone wax. The six remaining animals which showed roentgenographic and gross evidence of epiphyseodesis on exploration thirty days after the fusion served as controls. The right and left femora were removed from each of the experimental animals forty-five to 120 days after the second procedure.

The results in this group were similar to those observed in the first group. All the animals showed shortening and valgus which were not closely related to the duration of the experiment. The shortening and deformity were related to the remaining length of the intact, growing epiphysis and to the extent of the reactive bone bridging the epiphyseal line as seen in the histological sections.

DISCUSSION

The studies of Selye and Hellstadius have indicated that the epiphysis possesses a regenerative potential. Lacroix has shown that grafts of epiphyseal cartilage induce enchondral ossification in remote tissues, and that the potential is augmented when the peripheral portion of the cartilage is transplanted. In the investigations reported here, several factors should be considered in relation to the lack of observable regeneration of enchondrogenesis. Previous research has stressed that such potency is greatest in very young animals, although the work of Hellstadius was done with two-month-old rabbits. In the experiments described in this report, the ossification groove of Lacroix, which he regards as the area of the greatest regenerative capacity, was part of the resected segment in the animals of each group.

The remainder of the epiphyseal plate continued to function in an uninterrupted manner. The histological observations in this study emphasized that the important and

perhaps the determining factor in causing deformity was the osteogenesis secondary to operative trauma which could not be fully controlled by interposition media. The extent of the surgery and the intensity of the reactive bone changes determined the resulting deformity. This deformity, produced by the development of bone trabeculae which united the terminal epiphyseal plate to the metaphysis, was greater in the group of animals subjected to more radical resection in which the operative reaction could not be minimized by interposed material.

Some sections of bone from animals in which even a minor deformity had developed showed a thin line of bone trabeculae uniting the periphery of the epiphysis to the metaphysis. Therefore, in these animals a deformity equivalent to those with a broader area of union should have developed. The experiments of Odelberg-Johnson may explain this discrepancy. When he fused the vertebral laminae of young rabbits, he observed that vertebral body growth continued despite the spine fusion, but numerous minute defects appeared in the fused areas at the disc levels which were subsequently ossified, causing elongation of the graft. Such defects represented trabecular fractures produced by the distracting force of spinal growth, and ultimately caused the fused spinal segment to grow and to lengthen. It is possible that when only a limited area of fusion between the metaphysis and epiphysis developed in these animals, the normal growth force from the remaining cartilage plate proved great enough to effect a gradual elongation of the fused area. This would explain the phenomenon of growth occurring in the lateral cartilage despite microscopic evidence of epiphyseal fusion.

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Fractures and Dislocations of the Cervical Spine

An End-Result Study*

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In this article is reported the author's experience in the orthopaedic treatment of seventy-seven patients who had suffered eighty-seven fractures of the cervical spine, dislocations of the cervical spine, or both. Most of the patients were treated on the Fracture Service or in consultation on the Neurosurgical Service of the Massachusetts General Hospital; several were treated in consultation in the Marine Hospital of the United States Public Health Service in Boston. The series of patients was accumulated during the years 1940 through 1950. All of these patients, except fourteen, were seen at follow-up examination by the author at one to twelve years after definitive treatment had been instituted in one of these hospitals. For the sixty-three patients who survived the injury, the mean follow-up period was five years. Fourteen of the seventy-seven patients died from complications resulting directly from involvement of the cord, from within a few hours after injury to seven months after the injury.

CORD INJURY

There is always danger that the cord and nerve roots in the close vicinity of the injury will be damaged when a fracture or dislocation occurs in the cervical spine. This danger is present from the moment of injury until the fracture or dislocation has been reduced and the stability of the column has been restored. In this series of patients treated for eighty-seven injuries of the cervical spine, there was complete interruption of cord function immediately following the injury in approximately one in every five patients; there was immediate onset of partial loss of cord function in one in every four patients; and there was definite evidence of nerve-root pressure immediately following the injury in approximately one in every five patients. In only twenty-seven of the seventy-seven patients was there no sign of loss of cord or nerve-root function as a result of the injury. It is a sad commentary that in one in every ten patients symptoms of cord compression or an increase of cord symptoms developed subsequent to the time of original injury — during emergency care, during the time when the diagnosis was being established, during definitive treatment, or following reduction (Table I).

Cervical Injuries Dangerous to the Cord

The cord may be damaged in most of the more common injuries of the cervical spine. Interruption of cord function will be seen to occur in association with injuries resulting from both forcible flexion and hyperextension. It is apparent that a decrease of the anteroposterior diameter of the vertebral canal to such a degree that it approaches the diameter of the cord will result in cord compression. There are various proved mechanisms by which the lumen of the canal is encroached upon sufficiently to endanger or actually to compress the cord. Bursting fractures of the vertebral body (longitudinal compression) commonly result in backward displacement of bone fragments (Figs. 1-A, 1-B, and 1-C); often there are immediate symptoms of cord compression. A. S. Taylor, Schneider and Kahn, and Rogers [16] have reported the late onset of cord symptoms after failure to correct backward displacement of bone fragments. Such displacements are common in this injury. Relief of symptoms has followed decompression. Elsberg, Stookey [22, 23], Cramer and

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McGowan, Bucy and associates, and Barnes demonstrated that hyperflexion injuries of the cervical spine without vertebral fracture or dislocation may cause retropulsion of fragments of the intervertebral disc. It is also well known that disc displacements, disabling neurologically, may occur without specific injury. Anterior dislocation or unilateral rotatory dislocation may also result in cord damage (Figs. 2-A through 3-C). In such dislocations, Barnes has shown that cord compression is not possible until the dislocation of one or both of the inferior articular processes is complete and they lock. In the presence of complete anterior dislocation, there may be no cord damage whatsoever (Figs. 4-A through 4-D). If, however, the spine is extended while one or both of the inferior articular processes of the dislocated vertebra are anterior to the superior articular processes of the vertebra below, the author has shown that, in the lumbar region, the lower border of the vertebral arch may move downward and forward into the vertebral canal and compress the cord from behind (Figs. 5-A and 5-B). Posterior dislocation (Fig. 19) and hyperextension injuries may also result in cord damage. A. R. Taylor and Blackwood demonstrated at autopsy that posterior dislocation of a cervical vertebra may cause transverse

TABLE I

TIME OF ONSET OF NEUROLOGICAL SYMPTOMS

	Patients (*No.*)	(*Per Cent*)
Late onset of increase of cord symptoms * (all were anterior dislocations)	8	10
Immediate onset of symptoms of complete cord interruption **	15	20
Immediate onset of symptoms of incomplete cord interruption †	19	25
Symptoms of nerve-root pressure only ††	15	20
No neurological symptoms	28	36
Total	77	100

* Cases 3, 20, 37, 44, 45, 62, 63, and 66.
** Cases 2, 5, 7, 19, 25, 31, 32, 35, 46, 48, 50, 53, 71, 73, and 76.
† Cases 1, 6, 16, 18, 20, 22, 29, 30, 33, 37, 42, 44, 55, 60, 62, 63, 66, 67, and 77.
†† Cases 3, 11, 14, 21, 23, 26, 27, 28, 40, 45, 47, 57, 61, 72, and 74.

compression of the cord. This occurred in one patient in this series (Case 76). The dislocation may undergo spontaneous reduction without any immediate roentgenographic evidence of injury. A. R. Taylor also demonstrated on the cadaver that forward bulging of the ligamentum flavum through hyperextension of the cervical spine, especially when it occurs opposite a marginal osteophytic ridge on the front wall of the canal, may cause compression of the cord. There is ample autopsy and clinical evidence to support this finding (Figs. 7-A and 7-B) (Cases 3 and 45). Bedford, Bosanquet, and Russell reported causal relationship between cervical vertebral osteophytes and cord degeneration.

In order to explain the cord damage which sometimes occurs in the absence of definite roentgenographic evidence of injury to the vertebral column, it was long held that a dislocation had taken place, immediately followed by spontaneous reduction. The reduction

Fig. 1-A: Case 10. A bursting fracture of the fifth cervical vertebra as the result of diving into shallow water. The posterior fragments have been displaced backward into the vertebral canal.

Fig. 1-B: In the anteroposterior roentgenogram, the centrum appears split vertically in the sagittal plane. The lower part appears jammed into the concavity of the upper surface of the vertebral body below. In the superior portion there is definite lateral displacement of fragments; the superolateral processes do not clasp the body above but have been pushed laterally.

Fig. 1-C: The result two years later. There was complete and lasting freedom from cord symptoms (eleven-year follow-up), no pain, and full pre-injury activities.

FIG. 1-C

FIG. 1-B

FIG. 1-A

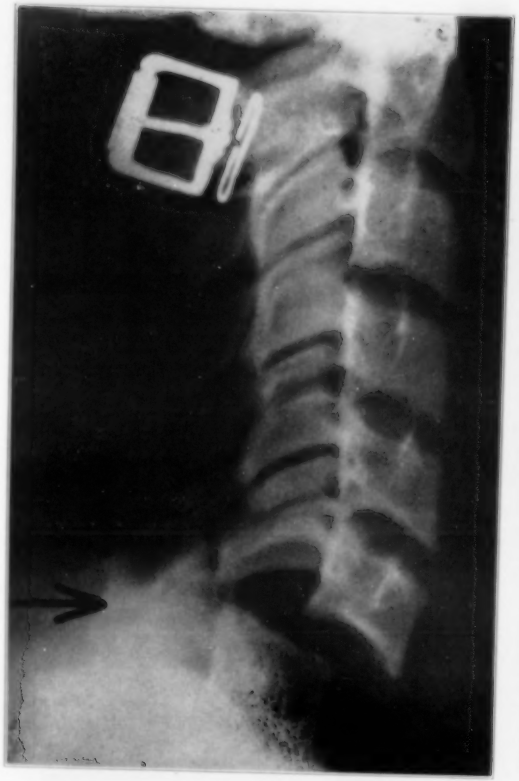

FIG. 2-A

FIG. 2-B

FIG. 2-C

Fig. 2-A: Case 30. A complete anterior dislocation of the sixth on the seventh cervical vertebra. There were symptoms of partial loss of cord function immediately after the injury; improvement neurologically was noted very shortly afterward. Reduction was easily completed at operation after several days of halter traction. (Reproduced from "Treatment of Fracture-Dislocation of the Cervical Spine" by W. A. Rogers, J. Bone and Joint Surg., **24**: 251, Apr. 1942.)

Fig. 2-B: The result after eight years. Roentgenogram made in maximum flexion.

Fig. 2-C: Maximum extension. Fusion was solid; there were no neurological symptoms; there were no complaints; the patient does full pre-injury activities as a dairyman.

FIG. 3-A

Fig. 3-A: Case 1. Lateral roentgenogram showing a unilateral rotatory dislocation of the second on the third cervical vertebra. There were symptoms of partial interruption of cord function immediately after the injury; these disappeared in a few days. Reduction by skull traction was attempted without success, but was achieved at open operation.

FIG. 3-B

FIG. 3-C

Fig. 3-B: The result six years afterward. Maximum flexion.

Fig. 3-C: Maximum extension. The patient resumed full pre-injury activities as a truck driver in ten weeks.

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 69. Anterior dislocation of the fourth on the fifth cervical vertebra, four months after an automobile accident. He had received no treatment. There were no symptoms of loss of cord function.

Fig. 4-B: Strong skull traction resulted in only slight improvement in position.

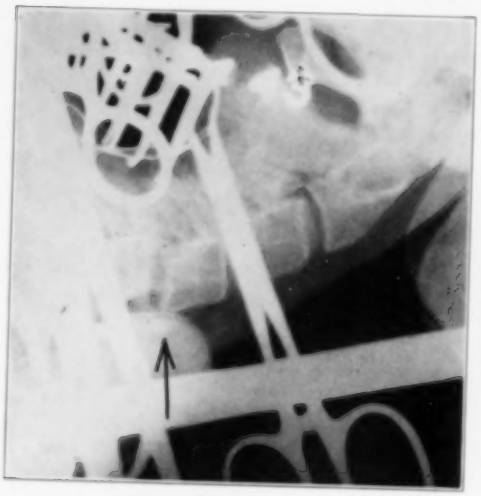

FIG. 4-C

FIG. 4-D

Fig. 4-C: Roentgenogram made during operation. Almost complete reduction was obtained by slowly levering the inferior articular processes backward on the superior processes of the vertebra below, as fulcra. The two vertebrae were wired together and fused.

Fig. 4-D: The result five years after fusion. Full pre-injury activities. No loss of cord function.

was assumed to be due to recoil of the column resulting from muscle action; the dislocation was believed to cause the cord damage. No definite evidence in support of this explanation appears to have been reported and the concept has been widely disclaimed as highly improbable. In 1939, however, the author [17] reported autopsy findings in a thoracic spine which can be interpreted on no other basis than that spontaneous reduction occurred following dislocation (Figs. 8-A through 8-D). It is also apparent from the specimen that while the cord may be compressed during the phase of dislocation, the obvious cause of compression is the retropulsion of disc fragments into the vertebral

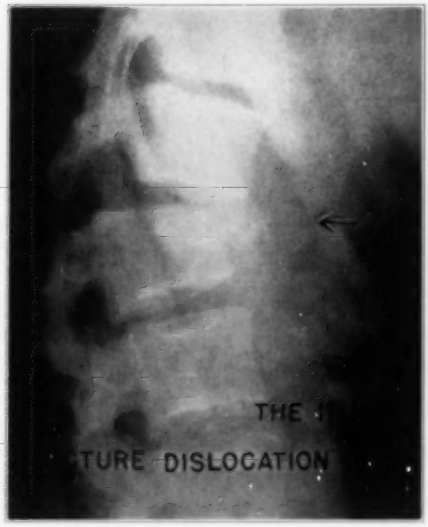

FIG. 5-A

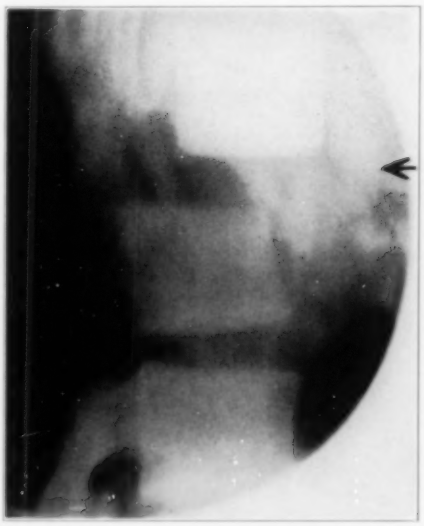

FIG. 5-B

Fig. 5-A: Anterior fracture-dislocation of the first upon the second lumbar vertebra. The patient had been thrown from an automobile. There was little immediate evidence of root pressure. A few days later he was transferred from a distant hospital with an increase in motor and sensory paresis in both lower extremities. He could still move his lower limbs. Reduction was attempted by traction-extension without anaesthesia.

Fig. 5-B: This roentgenogram shows the extent of the replacement obtained. The flexion element of the dislocation had been corrected, but replacement posteriorly had been blocked by the superior articular processes of the vertebra below. At this point there was an abrupt and almost complete motor and sensory loss in the lower extremities. Open operative reduction was immediately carried out under local anaesthesia. At operation, when the vertebral arches were exposed, the inferior articular processes of the dislocated vertebra lay anterior to the superior processes of the vertebra below. As a result of the extension, the arch of the dislocated vertebra had moved downward and slightly forward, decreasing the diameter of the canal and compressing the dura and cauda equina between its lower edge and the posterosuperior margin of the vertebra below. Finally the posterior elements of the two vertebrae had locked preventing further extension. The locked processes were disengaged by spinal flexion, were manipulated into normal alignment, and then reduced by extension, thus decompressing the cauda equina [18]. Subsequently, there was full return of motor and sensory function. (Reproduced from "Cord Injury During Reduction of Thoracic and Lumbar Vertebral-Body Fracture and Dislocation" by W. A. Rogers, J. Bone and Joint Surg., **20**: 692, July 1938).

canal. The roentgenograms of the specimen show narrowing of the intervertebral space. It is well known, however, that backward displacement of disc tissue can occur without narrowing of the involved disc space.

EMERGENCY TREATMENT

Protection of the Cord in Cervical Injuries

Because of the frequent association of loss of cord function with injury of the cervical spine, it is the responsibility of the trained aide who is first called upon to care for the patient with a neck injury to institute emergency measures which will protect the cord. Traction applied in the direction of the long axis of the spine in the neutral position will protect the cord which has escaped injury at the time of or subsequent to fracture or dislocation of the cervical spine, at least in a high proportion of cases, and will prevent further cord injury when damage has already occurred (Table II). Traction is applied to the cervical spine, as first aid, by means of an adjustable traction neck brace (Fig. 9). The brace is so constructed that it exerts a constant pressure against the chin and occiput in the cephalad direction and against the chest and shoulder girdle in a caudad direction, thus exerting traction on the cervical spine. During the past thirteen years such a brace has been used successfully as a routine measure to protect the cord in the presence of injury of the cervical spine. The brace must be worn at all times when the patient is

FIG. 6-A

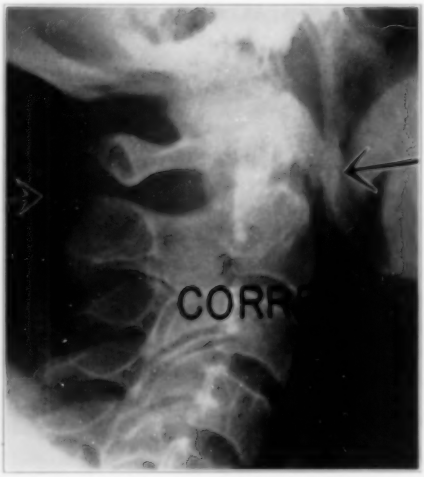

FIG. 6-B

Fig. 6-A. Case 50. Lateral roentgenogram of a posteriorly dislocated atlas on the second cervical vertebra with fracture of the odontoid process and lateral articular processes of the second cervical vertebra. She had fallen down stairs landing on her face. This had occurred shortly before admission to the hospital. There was evidence of almost complete loss of cord function.

Fig. 6-B: This roentgenogram shows the reduction obtained by skull traction.

FIG. 6-C

FIG. 6-D

Figs. 6-C and 6-D: The appearance of these vertebrae seven years later. While greatly improved neurologically at that time, she was still unable to work although she could care for herself in an institution for the partially disabled. There was a normal range of cervical motion.

being moved from place to place, as in transfer to and from the x-ray department, to and from surgery, and during the application of tongs for skull traction. No cord injury occurred in any of the patients during these years while wearing one of these braces.

The traction force must be applied in the direction of the long axis of the neck in the neutral position. The importance of keeping the direction of the traction in neutral cannot be overemphasized. The term *neutral*, as applied to the cervical spine, may be defined as that position in which there is a slight amount of extension, that is, one of slight lordosis. Since both flexion and extension from the neutral position have been

TABLE II

RESULTS OF SKULL TRACTION IN THE REDUCTION OF FRACTURES AND DISLOCATIONS AND THE PROTECTION OF THE CERVICAL SPINAL CORD

No. of Cases	Total Time of Traction	Average Time of Traction	Cord Injury During Traction	Complete Reduction	Prior Complete Reduction Maintained	Satisfactory Reduction Maintained	Failure of Reduction
48	326 weeks	6.8 weeks	0	29	8	6	5
				37 (77%)		(12.5%)	(10%)

demonstrated to cause cervical-cord compression in injuries of the cervical spine, flexing and extending forces are to be avoided, at least until the nature of the injury has been determined.

For the brace to be effective, moderate pressure is necessary on the chin and occiput. For this reason the brace can be worn effectively for a few hours only. The pressure is then lessened for a short time, during which time the patient must be inactive. When traction is to be resumed, the brace is first shifted slightly to change the points of maximum pressure.

The traction brace must be worn from the earliest possible moment after the injury until the patient is safely in bed in the hospital and skull traction has been applied.

Neck injuries require that the patient remain recumbent until stability has been restored.

When there is sensory paralysis, hard objects, such as pocket knives and pliers, must be removed from pockets as soon after injury as feasible in order to prevent the development of pressure necrosis.

THE DIAGNOSIS

The diagnosis is made on the basis of the roentgenographic and neurological examinations. Anteroposterior, lateral, and right and left oblique roentgenograms of the entire

FIG. 7-A

FIG. 7-B

Fig. 7-A: Anterior dislocation of the fifth on the sixth cervical vertebra in an old man with marked hypertrophic changes (marginal lipping).

Fig. 7-B: While under halter traction for about one hour he became paraplegic and a complete spinal-fluid block developed. The roentgenogram made at that time shows reduction and hyperextension at the site of injury.

FIG. 8-A

FIG. 8-B

Fig. 8-A: Sagittal section of an autopsy specimen of the decalcified sixth and seventh thoracic vertebrae. (Warren Museum, Harvard Medical School, Specimen No. 12736.) The patient, aged forty-three had fallen four stories from a roof to the sidewalk below. He had sustained a fractured skull, remaining unconscious, and dying on the third day after the injury. There is complete rupture of all binding ligaments and muscles. The sixth intervertebral disc is shattered. Fragments of the sixth disc and a hematoma are lodged between the dura and the posterior wall of the upper of these two vertebrae. Above, the disc fragments are seen lodged in the vertebral canal as high as the superior surface of the sixth vertebral body; below, disc fragments including a fragment of the cartilaginous end plate are found as far distally as the sixth disc, to the remnants of which they are still attached by a band. The posterior longitudinal ligament has been torn across opposite the middle of the sixth centrum. The mass of disc fragments presses upon the crushed cord.

Fig. 8-B: Paramedial sagittal section through one of the posterior articulations.

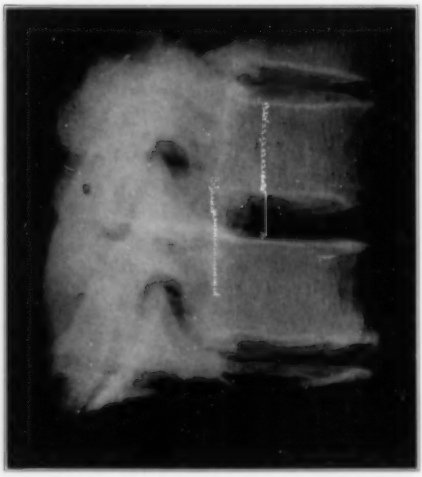

FIG. 8-C

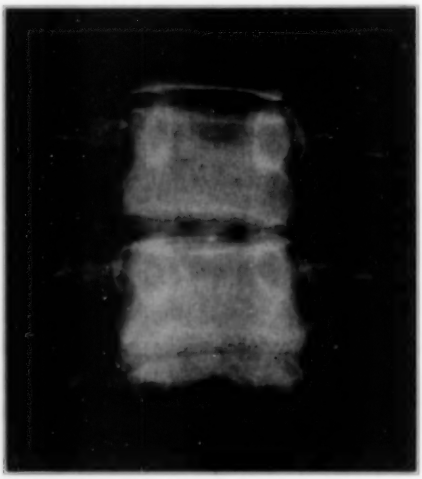

FIG. 8-D

Figs. 8-C and 8-D: Roentgenograms of the specimen. No evidence of fracture in the vertebrae. Marked anterior dislocation of the sixth on the seventh thoracic vertebra must have occurred, reduction having taken place spontaneously through the recoil of the column when the force had been spent.

cervical spine, as well as a roentgenogram made through the open mouth to show the odontoid process, are essential. A surgeon must be present when the roentgenograms are made because of the danger of cord injury as the patient is moved. The patient should not leave the x-ray department until satisfactory roentgenograms have been made.

TABLE III

INJURY DISTRIBUTION

	Number of Patients	Number of Lesions	Per cent
Wedge-compression fracture	6	9	10
Bursting fracture of atlas	2	2	2
Bursting fracture of vertebral body	10	12	13
Unilateral rotatory dislocation	8	9	10
Anterior dislocation	29	31	34
Anterior fracture-dislocation	8	9	10
Fracture ankylosed spine	1	1	1
Posterior dislocation	2	2	2
Hyperextension injuries	2	2	2
Posterior fracture-dislocation (including odontoid process)	2	2	2
Anterior fracture-dislocation (including odontoid process)	2	2	2
Fracture of the odontoid process	9	9	9
Unknown	3	3	3
	84 *	91 **	
	− 7	− 4	
Total	77	87	100

* Seven patients having two different injuries were counted twice.

** Four lesions were counted twice: two anterior and two posterior fracture-dislocations of atlas on axis.

TREATMENT

The first objective in the definitive treatment is the protection of the spinal cord during reduction and stabilization. When the safety of the cord has been reasonably assured through properly applied and adequate skull traction, reduction of the fracture or dislocation becomes the surgeon's next responsibility. In attempting reduction, restoration of the anteroposterior diameter of the vertebral canal, commonly decreased by the injury, to as near the normal as possible is of primary importance. To restore the injured vertebra to a normal or stable relationship with the vertebrae immediately above or below is the next important step. Finally, measures are undertaken to assure lasting stability in the injured spine either through internal fixation and fusion or by adequate external fixation until healing is complete.

FIG. 9

Fig. 9: Cervical-traction brace used in first aid and at all times when the patient is being moved about before the neck is stabilized.

Among the key articles in the field of skeletal traction for the reduction of fractures and dislocations of the cervical spine are those by Crutchfield, Hoen, McKenzie, and Barton.

Internal fixation by means of silk or wire loops, binding together the vertebral arches,

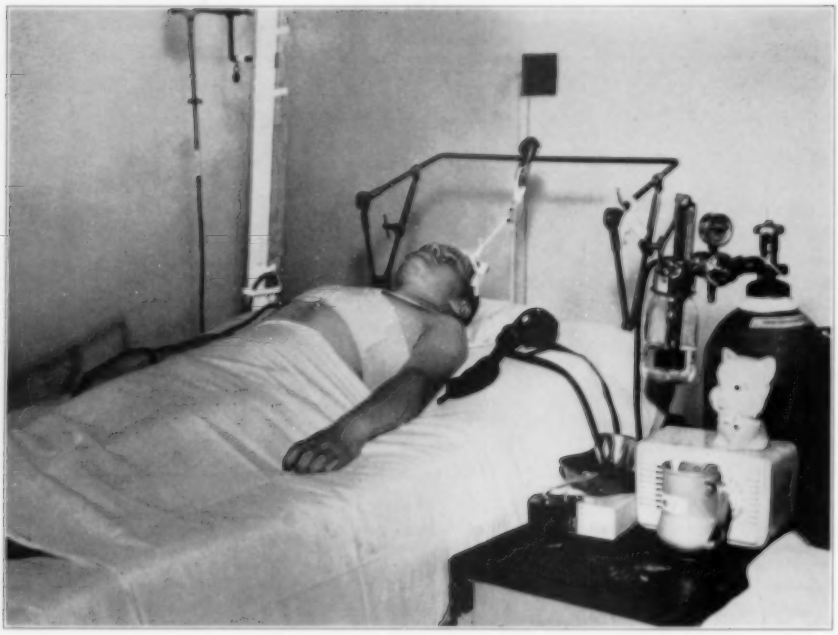

FIG. 10

Traction trolley attached to the adjustable head of the bed. This device, designed by the author, very much facilitates the care of the patient and adds to comfort. (Photograph obtained through the kindness of Dr. J. C. White.)

and posterior fusion by grafting in order to stabilize the cervical spine at the site of injury have been practiced occasionally for many years. Cone and Turner, in 1937, reported a substantial series of cervical-spine injuries treated by fusion with excellent results. In 1942, the author reported a series of eleven cases of fracture and dislocation of the cervical spine in which wire internal fixation and spine fusion had been employed to stabilize the injured cervical spine [18].

Skull Traction

The spinal cord is protected when the cervical spine is under skull traction. That this is true is attested by the fact that cord injury did not occur in a single instance while the neck was under skull traction for a total of 326 weeks in the forty-eight patients in whom it was used. The injuries in these patients represented almost every common type of fracture and dislocation of the cervical spine (Table II). In forty-three of forty-eight patients (90 per cent) complete reduction of the fracture or dislocation or a satisfactory position * of bone fragments was obtained as a result of the traction applied primarily to protect the cord. Skull traction is usually unnecessary after a few days when reduction has been followed by internal fixation and fusion. The more satisfactory devices in our experience for applying skull traction are Barton tongs and Hoen wires.

Care of the Patient

The traction cord is passed through a pulley attached to a trolley which can move freely on a horizontal track fixed to the adjustable head element of the bed (Fig. 10). This device, designed by the author, makes it possible for the patient to lie on either side or on

* One may arbitrarily accept as a satisfactory position one with less than three-millimeters decrease in diameter of the lumen of the vertebral canal.

FIG. 11-A

FIG. 11-B

Figs. 11-A and 11-B: Case 43. Anteroposterior and lateral roentgenograms showing an anterior dislocation of the atlas on the second cervical vertebra with non-union of a fracture of the odontoid process. The injury had occurred seven months before and the diagnosis had not been made. The examination neurologically was negative.

FIG. 11-C

FIG. 11-D

Fig. 11-C: Reduction was by skull traction. The roentgenograms were made after ten days of traction.
Fig. 11-D: This roentgenogram shows the appearance three years after the operation. There is solid bone fusion; the patient is symptom-free; and he has been at work for two and one-half years. The fracture of the odontoid process did not unite.

his back. He may also be raised to the semi-upright position when the head element of the bed is turned up. In this position he may read and feed himself with comparative ease. The period of recumbency is, therefore, less tedious and the nursing care is facilitated, especially in patients with cord injury in whose management frequent turning is important.

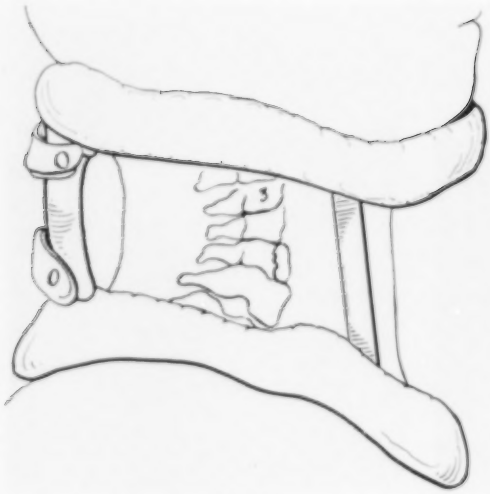

FIG. 12

Convalescent neck brace worn after operation for internal fixation and fusion until bone fusion is solid.

Reduction by Skull Traction

Anatomical reduction was effected by means of skull traction in twenty-nine of the forty-eight patients upon whom it was used. In the patients in whom reduction was complete, there were fourteen anterior dislocations, seven bursting fractures of the centrum, one bursting fracture of the atlas, one wedge-compression fracture of the vertebral body, three fractures of the odontoid process with displacement, one posterior dislocation, and two fracture-dislocations. In eight other patients, anatomical restoration was maintained by skull traction. In one patient, partial anterior dislocation had been present for seven months; skull traction was attempted and the dislocation was promptly reduced (Figs. 11-A through 11-D). However, skull traction failed to reduce a partial anterior dislocation present for four months (Figs. 4-A through 4-D). Reductions were arbitrarily considered satisfactory when the roentgenograms showed that there was less than three-millimeters decrease in the anteroposterior diameter of the vertebral canal. Such reduction was brought about in six other patients. In the total series there were five failures of reduction by skull traction; four were in patients with unilateral rotatory dislocations and one was in a patient with an anterior dislocation of four months' duration (Table II).

There were eight patients in whom fractures or dislocations were reduced by halter traction, by open reduction, or simply by positioning (three partial dislocations) and in whom reductions were then maintained without loss by skull traction (Table II).

Open Reduction

It is becoming more generally recognized that delayed onset of neurological symptoms or failure to regain function in damaged cords following injury to the cervical spine is causally related to the decrease in the anteroposterior diameter of the neural canal. This decrease in diameter is caused by displacement of bone, disc, or ligament as observed by clinicians for a number of years. More recently, it was studied by Kahn, and by Schneider and Kahn. Kahn pointed out that the dentate ligaments may prevent free movement of the cord posteriorly away from bone or disc fragments which have been displaced backward into the vertebral canal by injury. It may be demonstrated by anatomical dissection that the dural prolongations along the spinal-nerve roots resist backward displacement of the dura. Since the dentate ligaments are attached to the dura, the cord cannot move posteriorly away from the protrusion. When, however, these ligaments are divided in the vicinity of a fragment of bone or disc protruding posteriorly, the cord can be seen to move backward and may by this means be decompressed. Any definite decrease in the anteroposterior diameter of the bony canal must therefore be corrected when possible. Correction is brought about by reducing the fracture or dislocation by means of either skull traction or open operative manipulation[7, 18]. In the presence of irreducible bone displacement, Kahn and Schneider advocated laminectomy, followed by division of the dentate ligaments on either side in the vicinity of the displacement and by fusion.

Open reduction was undertaken in seven patients in the series here reported. In four

FIG. 13-A

FIG. 13-B

FIG. 13-C

Fig. 13-A: Case 52. Wedge-compression fracture of the fifth cervical vertebral body shortly after injury. There was no cord damage.

Fig. 13-B: The result at the end of eight years. Flexion.

Fig. 13-C: Extension. Bone fusion was solid; the patient had resumed work as a printer six weeks after the injury. He has remained symptom-free since operation.

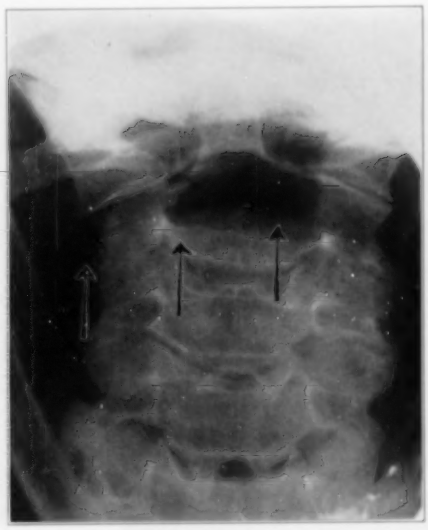

FIG. 14-A

FIG. 14-B

Figs. 14-A and 14-B: Case 64. Anteroposterior and lateral roentgenograms of a fracture at the base of the odontoid process and a crush fracture of the right superior articular process of the second cervical vertebra.

of these seven patients definite decrease of the front-to-back diameter of the vertebral canal had persisted in spite of skull traction. Three had unilateral rotatory dislocations and three had anterior dislocations. In one patient there was a free vertebral-arch fragment. Open reductions were complete in six and almost complete in one, the lumen of the vertebral canal being restored to normal in each instance. In one of these patients there was delayed onset of cord symptoms, due to manipulation during laryngoscopic tracheal intubation, a method henceforth abandoned. Two of the patients who underwent open reduction had cord symptoms at the time of operation; each regained complete cord function and remained neurologically normal for two to twelve years following operation. The dislocation had been present in one of the seven patients for four months prior to the reduction (Figs. 4-A through 4-D).

The operation of open reduction is performed with the patient prone, the head resting on the attachment of the table used in cerebellar surgery. Skull traction is maintained throughout. General anaesthesia is administered endotracheally through an intranasal tube. Laryngoscopic tracheal intubation must *not* be used. Identification of the injured vertebra during the operation has not always proved easy. The prominence of the spinous processes of the second, sixth, and seventh cervical vertebrae makes possible close approximation to the injured bone. Exact identification is then obtained roentgenographically by the use of a metallic marker. This has been routine practice since 1940, when an injured vertebra was erroneously not included in the fusion. The neural arches of the involved vertebrae, including the articular processes, are exposed subperiosteally. Reduction is then effected, usually by gentle instrumental manipulation applied through the spinous processes. If necessary, the head may be manipulated by an assistant, the appropriate maneuvers being clearly indicated by inspection of the exposed neural arches. In long-standing anterior dislocation (Figs. 4-A through 4-D), it may be necessary in order to accomplish reduction to lever with an appropriate instrument the displaced articular processes back into normal relationship with their articulating fellows. As an alternative, gentle instrumental manipulation may be applied to the spinous processes following partial excision of one or more articular processes.

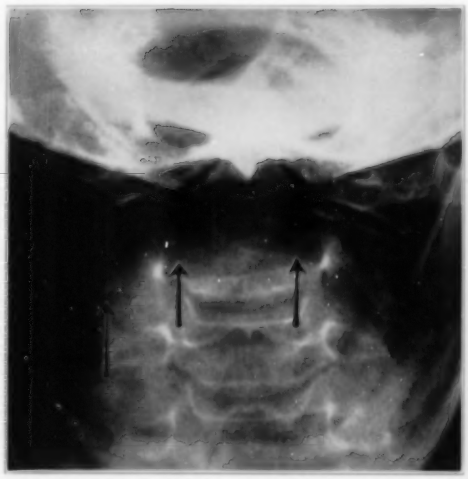

FIG. 14-C

FIG. 14-D

Figs. 14-C and 14-D: Only partial correction of the deformity was obtained by skull traction.

Fig. 14-E: The result three years after injury. There is evidence of traumatic arthritis of the right lateral articulation between the axis and atlas and depression of the right articular process of the axis. The patient was symptom-free.

FIG. 14-E

Wire Internal Fixation and Fusion [18]

Following reduction, excellent internal fixation is provided by binding together with wire the bases of the spinous processes of the injured vertebrae and those of the vertebrae next above and below. Bone grafts are applied to the exposed cortical surfaces, denuded of periosteum, between the laminae and between the spinous processes. Stabilization by this means assures the lasting safety of the cord (see Fig. 5 on page 249, Vol. 24, *The Journal of Bone and Joint Surgery*). Solid bone fusion was accomplished by means of this technique in thirty-six of thirty-nine patients.

Internal fixation and fusion achieved by this procedure prevent recurrence of displacement, shorten the period of recumbency in traction, and allow the patient to be up and about and to leave the hospital at an early date. Patients with loss of cord function can be mobilized much sooner. Early resumption of light activities is permitted and resumption of full pre-injury activities without too great a loss of time is made possible in a high proportion of cases (Table IV). This form of stabilization has protected the cord from attrition in this series.

In the thirty-nine patients, each vertebra which had been fractured or dislocated was fastened to the adjoining injured vertebra, and to the next normal vertebra, above and below, in a normal or nearly normal relationship. Fixation was accomplished by means of figure-of-eight loops of 22-gauge stainless-steel wire, which bound together the bases of the spinous processes. The wire prevents hyperextension and makes it possible for the posterior

articulations to block flexion. Autogenous cancellous iliac-bone grafts, in the form of slabs, three centimeters by one centimeter by 0.3 centimeter were then packed in layers, bridging the intervals between the laminae, about the bases of the spinous processes, under the wires, and between the spinous processes.

FIG. 15-A

All patients who were free of cord symptoms at the time of operation (there were thirty-three) were allowed to be up and about in a few days to several weeks after the date of operation. On becoming ambulatory they were equipped with a restraining cervical brace (Fig. 12) which was worn uninterruptedly until solid fusion had been demonstrated beyond any doubt. The brace was designed and worn as a restraint to prevent wide ranges of motion of the neck; it was not at all intended to immobilize. By restricting motion, all undue stresses on vertebral cortices at the points of contact with the wire loops were avoided. Ryerson and Christopher showed that unrestrained motion will result in erosion of the bone by the wire and stability will be lost before bone fusion has taken place.

All patients who were free of symptoms of cord compression left the hospital in the ambulatory state.

FIG. 15-B

FIG. 15-C

Figs. 15-A and 15-B: Case 13. Anteroposterior and lateral roentgenograms of a bursting fracture of the atlas. Notable is the fracture through the groove of the vertebral artery in the lateral view and the fracture through the right lateral mass including the attachment of the anterior arch of the atlas to the right lateral mass of that bone in the anteroposterior view.

Fig. 15-C: The reduction obtained by skull traction.

FIG. 15-D

FIG. 15-E

Figs. 15-D and 15-E: The result twelve years after the accident. The patient is symptom-free. The fracture occurred when the horse he was riding in a steeplechase refused a jump; he was thrown over the fence and landed on top of his head, bursting the first cervical vertebra. There were no cord symptoms.

END RESULTS

The result in each patient was determined by physical and roentgenographic examination (at one to twelve years after the beginning of definitive treatment, the average being five years) (Table IV). Fourteen of the seventy-seven patients died from complications resulting directly from involvement of the cord from a few hours to seven months after the injury.

Internal Fixation with Fusion (Thirty-nine Patients)

Fusion: The criterion of solid bone fusion in the cases of operative stabilization was absence of demonstrable change in the relationship of the fused vertebrae to each other in two sets of comparable lateral roentgenograms made in maximum flexion and maximum extension one week apart (Figs. 2-A, 2-B, and 2-C). In all but two patients, fusion took place. The time required for fusion was eight to twelve weeks, usually eight weeks.

Recurrence: No patient in whom the involved vertebrae were fused together, surgically, suffered a recurrence of dislocation or of deformity.

Neurological status[5]*:* In no patient who was free of neurological symptoms before operation did they develop subsequent to solid fusion. All patients who had neurological symptoms indicative of partial loss of cord function at the time of operation (Cases 20, 29, and 37) were so improved that their neurological status was nearly normal.

One patient had had four episodes of quadriplegia during the preceding nineteen years because of a chronic progressive anterior dislocation of the atlas on the second cervical vertebra (Case 20). A laminectomy was done; the dura was not opened. Fusion was effected between the occiput and the second and third cervical vertebrae. Immediately after surgery he was again quadriplegic. Slowly thereafter his condition improved, becoming nearly normal. At the last follow-up examination, seven years after surgery, he was symptom-free with the exception of cervical motion which was limited to a few degrees. In this patient, there were also advanced hypertrophic arthritic changes. He was sixty-four years of age and had retired. Reproductions of the roentgenograms appear in Figures 12-A and 12-B in a previous article[15]. (See Tables V, VI, and VII.)

Pain: None of the thirty-nine patients who underwent fusion complained of neck pain subsequent to wound healing.

Functional restoration: This was complete in the range of cervical motion consistent

TABLE IV

RESULTS OF TREATMENT OF SKELETAL INJURY

	Including Internal Fixation-Fusion in 39 Patients			Not Including Internal Fixation-Fusion in 33 Patients		
Anatomical reduction (obtained or maintained)						
By skull traction	19			14		
By open operation	6	29		..	21	
By halter traction	4			7		
Satisfactory restoration of lumen of vertebral canal (decrease less than 3 millimeters)			31			31
By skull traction	1			5		
By open operation	1	2		..	10	
By halter traction	..			5		
Present in old injury			7			2
Unsatisfactory restoration of lumen of vertebral canal (decrease more than 3 millimeters)						
By skull traction			..			..
By halter traction			..			..
Present in old injury			1			..
Stability						
Operative bone fusion	37			..		
Time of bone fusion	8–12 weeks	37 (95%)				9 (36%)
Spontaneous (interbody) fusion	..			9		
Time of spontaneous interbody fusion				4–18 months		
Instability						
Failure of operative fusion	2 (5%)			..		
Recurrence of dislocation	..			4 (16%)		
Complications	2 (5%)			2 (6%)		
Anaesthetic death	1 (laryngoscopic intubation)			1 (inadequate anaesthesia)		
Temporary aggravation of neurological symptoms	1 (laminectomy — old injury)			..		
Halter traction, restlessness, death	..			1		
Return to Work	33 of 34 (97%)			22 of 27 (81%)		
Time of return	5.4 months			9 months		
Irreparable cord injury or old age	5			6		

with age in all of the patients except four. Two patients underwent fusion of the occiput to the first, second, and third vertebrae; these retained 10 per cent and 20 per cent of rotation, respectively. Two patients who underwent fusion of the first and second vertebrae retained 50 per cent of rotation.

TABLE V

COMPLETE AND ALMOST COMPLETE INTERRUPTION OF CORD FUNCTION

	Improvement to Normal or Almost Normal	Moderate Improvement	Slight or no Improvement	Return to Work	Death during or after Treatment	Death before Definite Results of Treatment
Anatomical reduction and operative or spontaneous fusion — 9 patients.	5 (55.5%) Cases 2, 29, 42, 76, and 77	—	4 (44.4%) Cases 5, 46, 66, and 73	4 Cases 2, 29, 42, and 77	2 Cord death — 1 Pneumonia — 1 Cases 66 and 73	—
Satisfactory reduction without operative or spontaneous fusion — 11 patients.	1 (9%) Case 53	1 (9%) Case 50	9 (82%) Cases 3, 7, 25, 32, 44, 45, 62, 63, and 71	1 Case 53	8 Cord death — 4 Urinary-tract infection — 2 Pulmonary infaret — 1 Cases 3, 7, 25, 32, 44, 45, 62, and 63	—
Unsatisfactory * reduction but operative or spontaneous fusion — 1 patient. * More than 3 millimeters decrease in diameter of vertebral canal.	1 Case 20	—	—	—	—	—
Without result from treatment — 4 patients.	—	—	—	—	—	4 Cases 19, 31, 35, and 48
Total — 25 patients.	7 (28%)	1 (4%)	13 (52%)	5	10	4 (16%)

Return to work: Thirty-three of the thirty-nine patients who underwent operative fusion resumed work in an average of five and one-half months. Of the remaining six, three were quadriplegic and three had retired from work on account of age.

Failure of fusion: Fusion failed in two of the thirty-nine patients. In one (Case 34), the wire used for internal fixation broke. A considerable portion of one of the vertebral arches had been removed as a free fragment which was felt to be a menace to the cord. The patient had no further trouble from the injury in spite of the failure of fusion. The other patient (Case 45), a woman of sixty-two years, had advanced degenerative arthritic changes in the cervical spine with marked lipping. Her neck had been accidentally hyperextended during laryngoscopic intubation for endotracheal anaesthesia. She was found to have complete interruption of cord function following the operation and died the next day. Laryngoscopic intubation was forthwith stopped in this form of surgery of the cervical spine; there has been no further trouble since and intranasal tracheal catheterization has proved safe and effective in fifteen subsequent patients.

FIG. 16-A

FIG. 16-B

FIG. 16-C

Fig. 16-A: Case 77. Partial dislocation anteriorly of the fifth on the sixth cervical vertebra. The articular processes are still engaged, the dislocating forces having become spent before the displacement was complete. There had been partial loss of cord function immediately after the accident. Recovery neurologically began very soon afterward and in a few days was complete. Reduction was effected at open operation four months later. The vertebrae were fixed with wire and bone grafts were applied. Fusion was solid in eight weeks.

Fig. 16-B: The appearance of the spine one year later. Flexion.

Fig. 16-C: Extension. He had been regularly at work as a deep-sea fisherman for eight months.

FIG. 17-A

FIG. 17-B

FIG. 17-C

Fig. 17-A: Case 12. There was an anterior dislocation of the second on the third cervical vertebra together with a wedge-compression fracture of the body of the third vertebra. The pedicles of the second vertebra were fractured. There was present no dislocation of the posterior articulations between these two vertebrae. There was no evidence of interruption of cord conductivity.

Fig. 17-B: Reduction was effected by traction. The first, second, and third vertebrae were wired together and bone grafts were applied posteriorly across the vertebral arches of these three segments.

Fig. 17-C: Roentgenogram was made six months after the operation showing maintenance of the reduction and bone fusion. There were no symptoms; he had been at work for three months.

TABLE VI

PARTIAL INTERRUPTION OF CORD FUNCTION

	Improvement to Normal or Almost Normal	Marked Improvement	Moderate Improvement	Return to Work
Satisfactory reduction and operative or spontaneous fusion — 10 patients	8 (80%) Cases 1, 6, 22, 30, 33, 55, 60, and 67	1 (10%) Case 37	1 (10%) Case 16	8 (Average 6 mos.)

Operative fatality: One patient (Case 45) suffered fatal cord damage from cervical hyperextension incidental to laryngoscopic intubation.

Non-operative fatality: One patient who had operative fusion and who was quadriplegic succumbed to pneumonia two years after the operation.

Patients Treated without Surgical Fusion

Of the thirty-eight patients who were treated without surgical fusion, six died of cord damage, sustained at the time of injury, within a few days of admission to the hospital.

Reduction: Anatomical reduction was achieved or maintained in twenty-one of the remaining thirty-two patients — in thirteen by means of skull traction and in seven by means of halter traction. Incomplete reductions but stable relationships were achieved or maintained in ten — five by means of skull traction, and five by means of halter

FIG. 18-A

FIG. 18-B

Fig. 18-A: Case 56. An extension fracture of the ankylosed cervical spine through the level of the fourth intervertebral disc. In spite of complete ankylosis of the spine in flexion he had managed to earn his living as a truck driver. Shortly before admission he had fallen from his truck striking his forehead on the tailboard. There were no neurological symptoms. The extended position was maintained by skull traction with some improvement in his posture.

Fig. 18-B: Refusion took place spontaneously in the improved position in ten weeks and he resumed work ten months after the injury.

traction or by brace. Incomplete reductions could not be improved in two patients; one lesion was of long standing and one was accepted by the patient.

Recurrences: In spite of external fixation, there was recurrence in four of the thirty-two patients. In each instance, the injury was an anterior dislocation; in three of the four patients the sixth vertebra was dislocated on the seventh; in one, the fifth vertebra was dislocated on the sixth (Cases 6, 23, 42, and 59).

Spontaneous fusion: This occurred between adjacent injured vertebral bodies in eight of the thirty-three patients and was probable in a ninth. The time of interbody fusion could not be determined with precision for a number of reasons. Fusion had unquestionably taken place at three months in one patient and at eighteen months in another (the extremes). The average time for seven of the patients was probably about eight months. In one patient interbody fusion occurred not only at the site of injury but at the second disc above and the disc next below (Cases 23, 33, 39, 40, 42, 58, 59, 72, and 76).

Non-union: This occurred in two patients. Both had sustained fractures of the odontoid process (Cases 9 and 44). All other fractures united.

Pain: No patient complained of local or referred pain in this group once the injury had healed.

Functional restoration: There was a complete range of cervical motion consistent with age in all patients who survived the injury. As degenerative arthritic changes developed with advancing years, the range of motion became correspondingly limited. There seemed, however, to be no limitation directly attributable to the injury itself.

Return to work: Twenty-two of the patients who survived the injury returned to work in an average of nine months.

Cord injury during treatment: This occurred in two patients.

FIG. 19

Case 76. Lateral roentgenogram of a healed posterior dislocation of the third on the fourth vertebra which had been almost completely reduced eight years before. Interbody fusion occurred between the second and third, fourth and fifth, and fifth and sixth vertebrae. He had recovered almost to normal following quadriplegia.

One of these patients was sixty-four years of age. He had fallen downstairs one week before admission to the hospital and had been in bed since because of pain in the neck. On entering the hospital, he had no sign of cord injury; there was weakness of hand grip bilaterally. Roentgenograms disclosed a partial anterior dislocation of the fifth on the sixth cervical vertebra and the cervical spine was the seat of advanced degenerative arthritis with marked lipping. Halter traction was applied. An hour later signs of complete interruption of cord function had developed at the level of the fifth cervical vertebra. There was a partial block to the flow of cerebrospinal fluid. Roentgenograms made at that time showed that reduction had taken place. There was actual hyperextension of the fifth on the sixth cervical vertebra and marked lipping on the inferior margin of the fifth cervical vertebra posteriorly and on the superior margin of the sixth vertebra posteriorly. Cord function was not re-established and the patient died five weeks later. No autopsy was performed. He had been very restless while under halter traction; it seems probable that the cord was compressed between a bulging ligamentum flavum behind and marked marginal lipping anteriorly due to voluntary hyperextension. Had skull traction been employed this fatality would probably have been avoided.

Halter traction strong enough to be effective is too uncomfortable; uncontrollable restlessness may ensue and be disastrous.

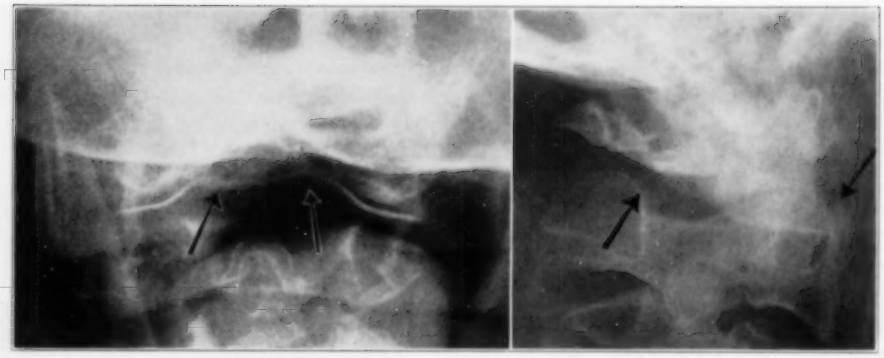

FIG. 20-A

Case 9. Anteroposterior and lateral roentgenograms of a fracture of the odontoid process. There was posterior dislocation of the atlas on the axis; the odontoid process was displaced backward with the atlas

FIG. 20-B

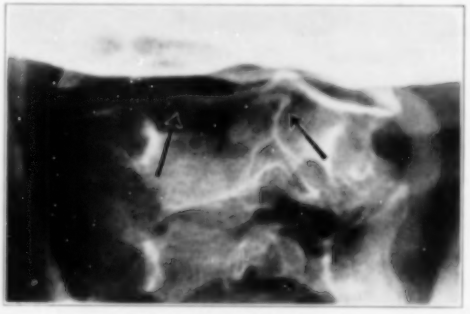

FIG. 20-C

Fig. 20-B: Reduction was obtained by skull traction and was almost complete.

Fig. 20-C: Although union of the fracture of the posterior arch had occurred within three months of the time of injury, non-union of the odontoid fracture was still present at follow-up examination, five years later. He was symptom-free, normally active, and had a normal range of cervical motion. The dislocation had not recurred. The examination neurologically was negative.

The second patient, seventy-five years old, fell two days before admission to the hospital injurying his neck. There was no evidence of cord or root compression. Roentgenograms disclosed an anterior dislocation of the fifth on the sixth cervical vertebra. Hoen wires were introduced into the skull without incident until the skin sutures were being placed where the local anaesthetic had evidently worn off. The patient, whose neck had been stabilized with a Thomas collar during the insertion of the Hoen wires, suddenly thrashed about. At once he went into shock and was found to have become quadriplegic. The next day the dislocation was found to have been reduced. The skull traction maintained the reduction and allowed adequate nursing care with frequent changes of position. The patient was comfortable at all times. The patient died six days after the onset of quadriplegia which was in all probability due to violent extension of the dislocated cervical vertebrae.

Cause of death: Thirteen patients in the group of thirty-eight patients treated without surgical fusion died as a result of the injury. Three patients died of cord damage within a few days of the injury before results of treatment could be noted. Three died of cord damage in spite of treatment in one to six days. Two died suddenly of massive pulmonary infarction, one at eleven days after injury and one at two weeks. Two in whom the bladder was paralyzed because of the cord injury died of urinary-tract infection. One died of cardiac failure; and two died as a direct result of definitive treatment, one from halter traction, and one from failure of local anaesthesia during application of skull traction.

MORE COMMON TYPES OF CERVICAL-SPINE INJURY

The common injury of the cervical spine is anterior dislocation of a vertebral body. Less frequent are bursting fractures of a vertebral body, unilateral rotatory dislocations,

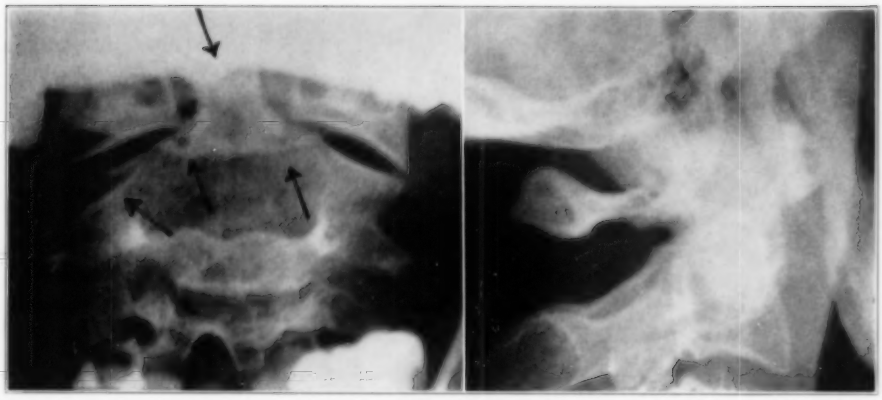

FIG. 21-A

Case 17. Anteroposterior and lateral roentgenograms of a fracture of the odontoid process. There was moderate displacement, the process being inclined to the right. There was a compression fracture of the right superior articular process of the axis.

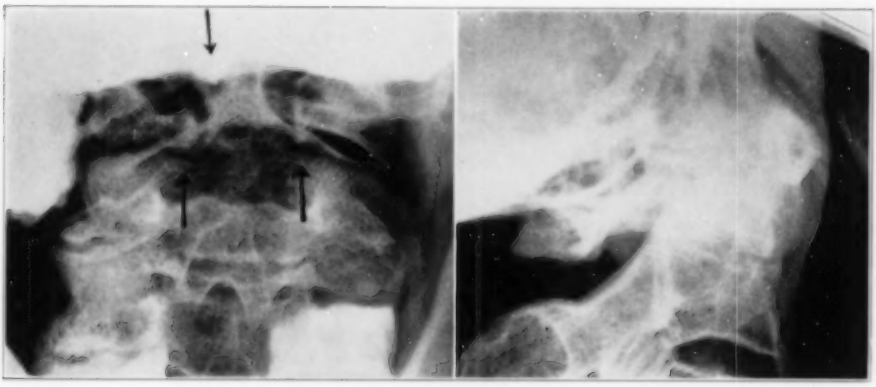

FIG. 21-B

Union of the fracture occurred with traumatic changes in the right superior articular process of the second vertebra, three and one-half months after the injury. The roentgenograms were made at follow-up examination at twelve years.

anterior fracture-dislocations, and uncomplicated wedge-compression fractures. Still less common appear to be fractures of the odontoid process, fracture-dislocations of the atlas on the second cervical vertebra, bursting fractures of the atlas, and posterior fracture-dislocations (Table III).

Wedge-Compression Fracture

Wedge-compression fracture of a cervical vertebral body is caused by violent hyperflexion of the cervical spine, the mechanism being essentially the same as that in wedge-compression fracture of the lumbar spine. Uncomplicated by dislocation of the vertebra next above, this injury was found nine times in six patients in this series of eighty-seven injuries of the cervical spine (Figs. 13-A, 13-B, and 13-C) (Cases 33, 51, 52, 53, 65, and 78). Four of the patients having wedge-compression fractures remained free of cord symptoms. One patient (Case 53) had sustained wedge-compression fractures of the fourth and fifth vertebrae in each of which the deformity was marked. Immediately following injury in this patient there was almost complete motor and sensory loss below the fractures. Within a few weeks there was nearly complete recovery of cord function. In the other patient

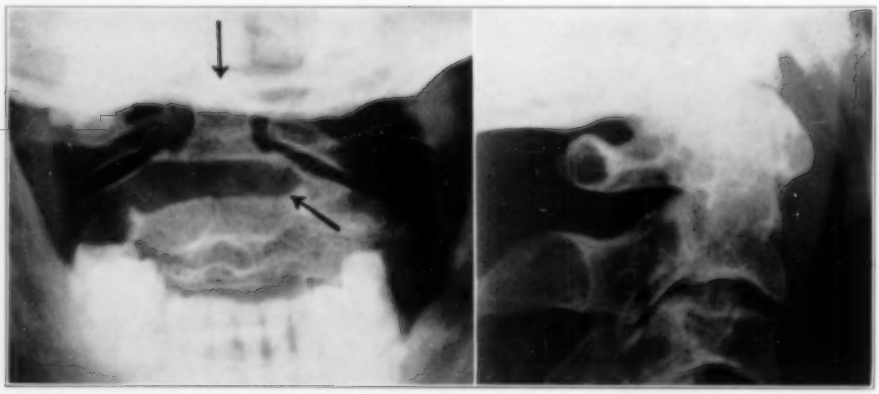

FIG. 22-A

Case 75. Anteroposterior and lateral roentgenograms of a fracture of the odontoid process. There was moderate displacement, the process being inclined to the left. There was a compression fracture of the left superior articular process of the axis.

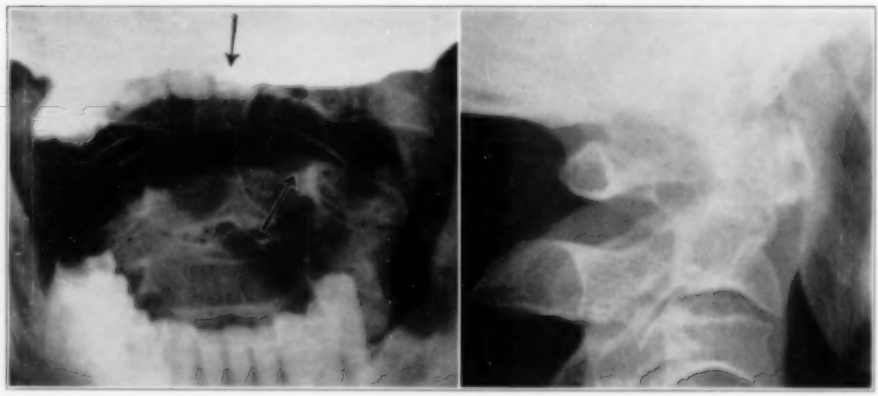

FIG. 22-B

Union of the fracture occurred with traumatic changes in the left superior articular process of the axis, four months after injury. The roentgenograms were made at follow-up examination at nine years.

(Case 33) with a wedge-compression fracture of the sixth vertebra, there was immediate onset of partial interruption of cord function. Complete recovery ensued. One patient (Case 65) sustained wedge-compression fractures of the fourth, fifth, and sixth cervical vertebrae.

Five of the fractures were reduced by traction. In these, reduction was almost complete. In two instances, restoration of shape of the deformed vertebra was satisfactory. Stabilization of the spine by fusion was effected in two of the six patients (Cases 52 and 65). All of the patients returned to work, four in five and one-half months. One with multiple major injuries, resumed work in twenty-four months and one with cord injury in fourteen months.

Bursting Fractures of the First Cervical Vertebra (Jefferson's Fracture)

As with the bursting fracture of a vertebral body in the lumbar region, bursting fracture of the first cervical vertebra results from violent compression in the long axis of the spine. Usually the patient is thrown or falls from a height in such a way that he lands on the top of his head. The condyles of the occiput, which are directed distally and

TABLE VII

NERVE-ROOT COMPRESSION

	Improvement to Normal or Almost Normal	Slight Residual	Moderate Residual	Return to Work
Satisfactory reduction and operative or spontaneous fusion — 20 patients	16 (80%) Cases 2, 11, 14, 21, 23, 26, 28, 30, 33, 42, 55, 57, 60, 72, 74, and 77	2 (10%) Cases 22 and 67	2 (10%) Cases 16 and 29	19 (95%) Average of 6.5 months
Satisfactory reduction without operative or spontaneous fusion — 2 patients	1 Case 41	1 Case 53	....	2 Average of 13 months
Unsatisfactory reduction but operative or spontaneous fusion — 2 patients	2 Cases 18 and 47	....	....	2 Average of 9 months
Total — 24 patients	19 (79%)	3 (12.5%)	2 (8%)	23 (96%)

laterally, are forced against the superior articulations of the atlas and, acting as a wedge, burst the ring of bone which constitutes the atlas. The resulting fracture may be single or multiple. The fractures posteriorly occur through the grooves of the vertebral arteries (Fig. 15-B); anteriorly, they may occur on either side at the junctions of the anterior arch of the atlas with the lateral masses. The lateral masses of the atlas tend to become displaced laterally (Fig. 15-A). This fracture does not appear to be a common one; there were two in this series (Cases 13 and 37).

No evidence of cord injury was present in either of the two fractures of this type; in one (Case 37), complicated by a fracture-dislocation of the second on the third cervical vertebra, there was partial interruption of cord conductivity in the vicinity of the injuries, not associated with the injury of the atlas.

Reduction was accomplished by skull traction in each of the two fractures and union occurred in both. One of the patients complained of pain after healing had taken place; he had at least half the normal range of motion. In this patient, an elderly man who had retired, the fracture was complicated by an anterior fracture-dislocation of the second on the third cervical vertebra. It was necessary to stabilize the spine by wire fixation and fusion. The other patient resumed full pre-injury activities in six months.

Bursting Fracture of the Vertebral Body

This fracture results from violent compression of the vertebral body between the body of the vertebra above and the body of the vertebra below. Commonly the injury occurs during diving into shallow water. The force is applied directly in the long axis of the spine. As in lumbar bursting fractures, the nucleus pulposus of the disc above and that of the disc below are forced into the core of the body, causing it to burst. Unlike some bursting fractures of lumbar vertebrae, the cervical body breaks into several large fragments (Fig. 1-A). The centrum, as seen in the lateral roentgenogram, appears to have been split into one or more anterior fragments and one or more posterior fragments. The sharp antero-inferior lip of the centrum above appears to have been driven into the fractured vertebral body, splitting it in the coronal plane. The anterior fragments appear to have tipped backward superiorly and become displaced forward inferiorly. The main posterior fragment is tipped forward superiorly and displaced backward inferiorly.

More important is the dangerous backward displacement of the main posterior fragments into the vertebral canal which may cause cord compression by decreasing the

anteroposterior diameter of the vertebral canal. Lateral displacements may cause nerve-root compression.

As seen in the anteroposterior roentgenogram, the vertebral body appears to have been split vertically in the sagittal plane (Fig. 1-B). In the inferior portion of the vertebral body there may be little or no lateral displacement of fragments. Presumably the lateral projections upward of the vertebra below prevent this. Superiorly, however, there may be slight but definite lateral displacement of fragments, for the lateral processes of the fractured vertebral body do not clasp the vertebral body above but are spread apart. Each lies lateral to the normal position.

In view of this skeletal displacement, neurological symptoms are to be expected and actually occur frequently. The injury is an especially dangerous one, as it is in other regions of the vertebral column. In this series, there were twelve such injuries (14 per cent) in ten patients, only two of whom escaped neurological changes (Cases 10 and 61). Two patients experienced immediate complete interruption of cord function (Cases 2 and 25). One improved only slightly in the seven weeks before he died of a massive pulmonary infarction; the other improved early in neurological status and was nearly normal eight months afterward. In three patients (Cases 55, 60, and 67) there was immediate partial interruption of cord function: two of these improved to nearly normal; one was normal. Three others had immediate symptoms of nerve-root compression; all improved subsequently to normal (Cases 11, 14, and 28).

Skull traction produced nearly complete reduction in each of the seven patients upon whom it was used (Cases 10, 11, 14, 25, 28, 60, and 67); all had fresh fractures (Fig. 1-C). Halter traction maintained a satisfactory position of fragments in one patient and plaster-of-Paris fixation in another. One patient with a minor deformity received no treatment; his fracture healed without incident.

Internal fixation and surgical fusion resulted in stable cervical spines in all eight patients upon whom operation was performed. In none of these patients did cord symptoms persist or recur. One quadriplegic patient (Case 25) died in seven weeks of pulmonary infarction. In one patient (Case 61) the fracture healed without treatment. Nine of the ten patients in this group resumed pre-injury activities in five months (Cases 2, 10, 11, 14, 28, 55, 60, 61, and 67).

Unilateral Rotatory Dislocation

Unilateral rotatory dislocation is caused by forcible lateral flexion and rotation of the cervical spine away from the dislocation, either as the result of muscle action or of indirect violence (Figs. 3-A, 3-B, and 3-C). The dislocation may also occur spontaneously in the rheumatoid cervical spine and in children with upper respiratory-tract infections during sleep. Such spontaneous dislocations appear to follow abnormal relaxation of the binding ligaments.

There were nine unilateral rotatory dislocations in eight patients in this series. In only two patients did symptoms of cord damage develop as a result of the injury. These symptoms, indicative of partial interruption of cord function, appeared in one patient who was struck on the head by a heavy plank and knocked down. They came on immediately after the injury and began to disappear in a few minutes (Case 1). Motor power returned in fifteen minutes. The second patient was thrown through the windshield of an automobile. Immediately he became quadriplegic and has remained so (Case 71).

With this type of injury, traction failed to reduce the dislocation in each of the five patients upon whom it was employed. In one (Case 8), skull traction partially reduced the dislocation between the atlas and the second cervical vertebra.

Six of the eight patients in this group were operated upon. Open manipulative reduction was successfully performed and a fusion operation was carried out in three of them (Cases 1, 15, and 45). The dislocated vertebra in each of the other three patients (Cases

24, 34, and 70) was fixed by a wire loop and was successfully fused to the vertebra below. Fixation and fusion in the latter three patients was performed without reduction because the superior articular process of the vertebra below had been fractured and could not, therefore, be relied upon to prevent recurrence of the dislocation and to immobilize the spine in the vicinity of the injury. There was no recurrence in the three patients in whom the dislocation was reduced. In four of the six patients operated upon fusion was obtained. One elderly patient (Case 45) with marked marginal lipping died of cord damage during laryngoscopic tracheal intubation. Intranasal intubation has been employed in all subsequent cervical-spine operations. There was one apparent failure of fusion (Case 34).

Six of the eight patients in this group resumed pre-injury activities in an average of five months (Cases 1, 8, 15, 24, 34, and 70).

Anterior Dislocation

Anterior dislocation without fracture of the body of the vertebra below occurs in the cervical spine chiefly as a result of shearing forces which violently displace one vertebra forward upon another; commonly the patient falls, landing on the back of the head. The ligaments which bind the vertebrae together posteriorly are notably weak. At operation they are found to have been extensively ruptured. Unless muscles act to maintain stability, the dislocating vertebra, no longer held by the posterior ligaments, is then displaced anteriorly carrying with it the vertebrae above.

If the superior articular processes of the vertebra next below the dislocating vertebra do not fracture as a result of the violence, the posterior elements of the dislocating vertebra are tipped forward and upward by the inclination of the articular facets. The displacement may result in partial or complete dislocation, depending upon the magnitude of the violence and the resistance of the column to it. When the inferior articular processes of the dislocated vertebra lie anterior to the superior articular processes of the next vertebra below, the dislocation is complete (Fig. 2-A). When they are still posterior, but displaced upward and forward the dislocation is partial (Fig. 16-A).

In the thoracic spine, anterior dislocation may occur with complete rupture of the disc and of the binding ligaments, the cord may be transected, and reduction may then take place spontaneously. It seems probable that similar spontaneous reduction may occur in the cervical spine (Figs. 8-A, 8-B, 8-C, and 8-D).

There were thirty-one anterior dislocations without fracture of the vertebral body in twenty-nine patients. In twelve of the twenty-nine patients (Cases 5, 6, 16, 19, 22, 29, 30, 31, 32, 42, 46, and 73), the symptoms of complete or partial interruption of cord function were present immediately following the injury, and in four patients (Cases 3, 44, 62, and 66) cord interruption occurred subsequent to the injury but before definitive treatment could be established. Seven patients (Cases 3, 19, 31, 32, 44, 62, and 66) died as a result of complete interruption of cord function (Tables V and VI).

Reduction of the dislocation was effected by traction or maintained by it in twenty-two of the twenty-nine patients upon whom it was employed, sixteen by skull traction and six by halter traction. Open reduction was performed in three patients in each of whom the reduction was complete (Cases 22, 30, and 69). Following reduction, the dislocated vertebra was fixed to the vertebra below with wire and bone grafts were applied in fifteen patients (Cases 5, 6, 16, 21, 22, 23, 26, 27, 29, 30, 46, 49, 57, 69, and 73). In one other patient an irreducible dislocation was fused with minor displacement (Case 18). In each of these sixteen patients solid bone fusion was obtained; thirteen of them returned to work, the average time of return being five months.

Recurrence of the dislocation following reduction and prolonged external fixation occurred in two patients in these series (Cases 42 and 59). In neither was internal fixation and fusion done following reduction; in both spontaneous (interbody) fusion occurred in eight and nine months, respectively.

Anterior Fracture-Dislocation

Anterior fracture-dislocation of cervical vertebral bodies is caused by forces similar to those which produce the anterior dislocation without fracture with the notable exception that there is considerable longitudinal compression present. As a result, a wedge-compression fracture is produced in the subjacent vertebra in addition to the forward displacement of the dislocated vertebra. If injuring forces are then not spent, one or both pedicles of the dislocated vertebra may fracture, provided the posterior articulations hold (Fig. 17-A). In eight patients there were nine anterior fracture-dislocations. Pedicle fracture occurred in two.

Symptoms of interruption of cord function were present in three of these patients, two (Cases 63 and 77) had complete interruption and one (Case 37) had partial interruption (Tables V and VI).

Reduction of the fracture-dislocation was effected by traction in four of eight patients (Cases 12, 39, 63, and 74). Open reduction was done in one (Case 77). In the two patients in whom traction failed to effect a reduction, the injury had occurred two and four months prior to treatment.

Internal fixation and fusion were employed in five patients (Cases 12, 37, 47, 74, and 77). In each of these, solid bone fusion was achieved and in none was there recurrence. Four of the five patients in whom fusion was done resumed work in an average of four months (Cases 12, 47, 74, and 77). In two patients (Cases 39 and 40) spontaneous fusion occurred. These patients returned to work in an average of eight months.

Fracture of the Ankylosed Cervical Spine

When a patient with rheumatoid ankylosis of the cervical spine falls, striking his head against an unyielding object, fracture of the ossified longitudinal ligament of the cervical spine may occur between two vertebral bodies. Angulation at the fracture site may be forward or backward, depending upon the direction of the fracturing forces.

One patient (Case 56) sustained this injury (Figs. 18-A and 18-B). He had fallen, face down, striking his forehead. There were no symptoms referable to the cord and no root symptoms. Correction of the pre-existing flexion deformity was easily effected by skull traction. Refusion occurred spontaneously in eight to ten weeks in a much improved position. The patient returned to work ten months after the injury.

One comparable case [20] was recorded in 1933, and four others [4] were recorded in 1949.

Posterior Dislocation

Posterior dislocation is the result of a shearing force applied to the face as in a fall forward, head first, displacing one vertebra backward upon another. A. R. Taylor demonstrated the clinical aspects of this injury in severe form and reported autopsy findings. The anterior longitudinal ligament is ruptured at the intervertebral disc immediately below the dislocating vertebra. This disc is completely torn transversely. In turn, the flaval and interspinal ligaments rupture and the vertebra is dislodged backward, drawing with it the intact posterior longitudinal ligament. Marked narrowing of the vertebral canal results and the cord may be crushed. Spontaneous reduction of the dislocation had occurred in Taylor's patient; the roentgenograms were negative although there was a complete transverse lesion of the cord.

There were two patients with posterior dislocations (Cases 7 and 76). It is unfortunate that all of the roentgenograms of Case 7 have been lost; also all of the roentgenograms of Case 76 except the six-year follow-up films have been lost. The lateral view of the cervical spine in Case 76 is shown in Figure 19; slight posterior displacement of the third on the fourth vertebra remains. Both patients immediately had symptoms of cord injury.

One patient (Case 7) had dived about fourteen feet into deep water but had struck his head against a submerged object. There was immediate loss of consciousness and complete interruption of cord function.

Reduction by skull traction was almost complete. He never regained cord function and died seven months later of urinary-tract infection. The other patient (Case 76) fell from a ladder about eight feet. From the resulting abrasions and contusions of the face it was evident that he must have landed on his face. There was immediate complete loss of cord function. Reduction was effected by halter traction and maintained by skull traction. There was early return of cord function which slowly continued until restoration was complete. There was spontaneous interbody fusion. He was observed over a period of six years following the injury.

Hyperextension Injuries

Reference has been made in a previous section of this article to the work of A. R. Taylor in which the role of extension of the cervical spine in cord injury was demonstrated. As a result of hyperextension, the flaval ligaments are compressed which causes them to bulge forward. This may result in cord compression, especially if there is narrowing of the canal due to marginal lipping anteriorly along the posterior borders of the vertebral body, which is present in many elderly people. There were two such cases in this series (Cases 3 and 45); both patients became quadriplegic through hyperextension and both died as a result. Hyperextension injury in each patient occurred during the course of treatment of the dislocation. Both patients were old and had advanced marginal lipping. In each case, permission for necropsy was denied.

A man (Case 3), sixty-four years of age, was admitted with a complete anterior dislocation of the fifth on the sixth cervical vertebra. He had fallen downstairs one week before, striking the back of his neck. There were mild symptoms of nerve-root pressure bilaterally in the distribution of the sixth and seventh cervical nerves. There was advanced marginal lipping (Figs. 7-A and 7-B). Halter traction was applied. He was reported to have become very restless soon afterward, tossing about in bed. When re-examined an hour after the application of the halter traction, he was found to have become quadriplegic from the fifth cervical level downward. There was a partial block of the cerebrospinal fluid. The roentgenograms showed reduction with hyperextension of the fifth on the sixth vertebra.

A woman (Case 45), sixty-two years of age, was admitted with a unilateral rotatory dislocation of the fifth on the sixth vertebra. There was advanced marginal lipping. She had fallen downstairs an hour before. Halter traction was applied without effecting a reduction and after eight days skull traction was applied for six days without success. She was then operated upon, open reduction being easily effected with the neck under skull traction. During tracheal intubation with the aid of the laryngoscope for endotracheal anaesthesia, the patient's neck was accidentally hyperextended. On recovering from the anaesthesia, she was found to be quadriplegic from the fifth cervical level. Laryngoscopic tracheal intubation is contra-indicated in surgery of the cervical spine.

Skull traction is indicated in cervical injuries in elderly people, especially in the presence of hypertrophic arthritis with marginal lipping of the vertebral bodies posteriorly.

We believe halter traction is contra-indicated in all cervical-spine injuries except those in children. If at all effective, it is uncomfortable in adults from undue pressure on bony prominences such as chin and occiput. It leads to restlessness and tossing about in bed which are always dangerous in these injuries and may be fatal.

Posterior Fracture-Dislocation

Posterior fracture-dislocation is caused by forcible hyperextension. A backward-displacing force is combined with compression in the long axis of the spine to drive one vertebra backward and downward on another, next below, fracturing the latter and dislocating the former posteriorly. A fall downstairs, head foremost, the victim landing on the face, is the usual type of accident. Cord damage may occur (Fig. 6-A).

There were two patients with this injury in this series (Cases 9 and 50). While posterior fracture-dislocations may involve lower cervical vertebrae, both patients with this injury sustained it in the first and second vertebrae. In one of these patients (Case 9) the vertebral arch of the atlas was fractured, evidently by compression against the arch of the second cervical vertebra; in both, the odontoid process was fractured. The odontoid process and the atlas were displaced together, posteriorly. Skull traction effected reduction in one (Case 50) and maintained the reduction secured through halter traction in the other

(Case 9). Union of the fracture of the odontoid process occurred in approximately four months in one patient (Case 50). Non-union of the odontoid process developed in the other (Fig. 20-C), although the fractures of the vertebral arch of the atlas united within three months of the time of injury. Internal fixation and fusion were not done. These patients were observed for five years and seven years, respectively; in neither was there recurrence of the dislocation.

There had been immediate almost complete loss of cord function in the close vicinity of the injury in one (Case 50); from this loss of function there was considerable recovery (she can care for herself), although the patient never regained economic independence. There never was any neurological damage in the other patient.

Fracture of the Odontoid Process

When fracture of the odontoid process occurs without dislocation of the atlas, the fracturing forces seem to be complex. Blockey and Purser have studied the mechanism of fracture of the odontoid process in a series of forty-six adults. They feel that any force which violently flexes, extends, or rotates the head on the neck may avulse the odontoid process. In the author's series, the roentgenographic appearance of the injured second vertebra suggests that the injuring mechanism in three of the five patients in his series was forcible flexion and rotation (Cases 17, 64, and 75). In each of these patients there appeared to be a crushing of the superior articular process of the second vertebra on one side in addition to the typical odontoid fracture described by Blockey and Purser (Figs. 21-A and 22-A). In two of the five patients in this category there had occurred a fracture of the odontoid process without displacement or crushing of either superior articular process (Cases 41 and 54).

In none of the five patients were there neurological symptoms, either of cord or nerve-root origin except one (Case 41) who complained of unilateral occipital pain, which proved to be temporary.

Reduction was effected by skull traction in one of the patients (Case 64). Halter traction failed to correct the deformity in the other two patients with lateral crushing.

Non-union occurred in one patient in the group; the injury consisted of a fracture of the odontoid without displacement and without crushing of either superior articular process. She had been treated by halter traction and a cervical brace. At last follow-up examination seven years after the injury, she stated she had been symptom-free for a number of years.

All five patients returned to work in an average of eight months.

Fracture of the Odontoid Process with Anterior Dislocation of the Atlas

Fracture of the odontoid process with anterior dislocation at the atlas apparently results from a violent shearing force directed anteriorly. The ligaments which bind the lateral articulations of the atlas to the second vertebra rupture and the atlas is displaced forward on the axis, carrying with it the odontoid process which fractures across its base. Should the odontoid process not fracture, the inevitable result must be death from high cord transection. Kahn and Yglesias have shown that if the dislocation is not reduced, there is a tendency for the displacement to progress until finally symptoms of cord compression appear. These neurological symptoms may be of insidious and slowly progressive onset, or they may develop abruptly into quadriplegia (Case 20).

There were two patients in this series with this type of injury. One patient (Case 43) had had the condition for seven months (Figs. 11-A and 11-B); there were no neurological symptoms. The other patient (Case 20) had had the condition for nineteen years, during which time he had had four episodes of quadriplegia from each of which he had recovered.

Complete reduction of the f acture-dislocation was obtained in one of these patients

(Case 43) by skull traction (Fig. 11-C). The atlas was then wired and fused to the axis. He made an uneventful recovery. He returned to work in seven months and has worked steadily since without any untoward symptoms over a period of five years. In the other patient (Case 20) the occiput was fused to the second vertebra, laminectomy of the atlas having been performed by Dr. John Hodgson. Following this operation the patient was almost completely quadriplegic. Later he regained cord function to a point which represented improvement neurologically over his preoperative condition. He never regained his capacity to work.

Summary of Fractures of the Odontoid Process (in Adults)

There were nine fractures of the odontoid process in this series. Five occurred without dislocation of the atlas on the axis; four occurred with dislocation of the atlas, two anteriorly and two posteriorly.

When displacement of axis fragments was present or there was dislocation of the atlas, skull traction was alone successful in effecting reduction (Cases 9, 43, 50, and 64).

Wire internal fixation and fusion seems indicated in the presence of old irreducible dislocation, old dislocation following reduction, and in the presence of atlanto-axial instability (Case 20).

Non-union of the odontoid process developed in four of the nine patients. Failure occurred in spite of there being no displacement of the odontoid process in two patients (Cases 9 and 41). One had been treated by halter traction and brace fixation; the other patient had been recumbent under skull traction for ten weeks. Neither had any untoward symptoms as a result; both resumed work. These patients were under observation for five and seven years following injury, one first reporting for treatment with established non-union. The other two instances of non-union developed in patients who had received no treatment for their anterior fracture-dislocations. One (Case 20) had been injured nineteen years before; the other (Case 43) seven months before. Both spines were fused; both united posteriorly, but in each the odontoid failed to unite even after the surgical fusion.

CONCLUSIONS

1. For the dangerous period between the time of injury and definitive treatment, and while being moved about during definitive treatment, the patient should be recumbent, at all times, on a firm stretcher or bed. An adjustable traction neck brace should be worn during these times, applied in the long axis of the spine in the neutral position.

2. Skull traction is the best proved means of protecting the cord during definitive treatment of cervical-spine injuries.

3. Skull traction will accomplish reduction and maintain it in a high proportion of injuries. It is comfortable and greatly facilitates nursing care.

4. Complete reduction is ideal; satisfactory reductions may include those in which there is less than 0.3 centimeter of decrease in the anteroposterior diameter of the vertebral canal. Open reduction was accomplished in seven patients, in six of whom skull traction had failed.

5. Internal fixation and surgical fusion provide reliable stabilization of the injured vertebrae. They appear to protect the cord against attrition in patients with a vertebral-canal diameter of less than normal.

6. The treatment of cervical-spine injuries is highly specialized; technical errors in treatment may be fatal. A trained and experienced operating team is essential.

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Repair of a Defect in the Shell of the Snail *Helix aspersa* *

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A major problem in the study of calcification of mammalian tissues such as bone, cartilage, and teeth has been to determine the contributing functions of cells, fibers, and ground substance during the various stages of the formation and calcification of the matrix. It is possible that a study of calcification in lower animals may provide information that will help to solve this problem. This paper presents the results of a biological study of the repair of a shell defect in the terrestrial gastropod *Helix aspersa*.

A defect in the shell of a snail is repaired by the deposition of calcium carbonate in an almost completely cell-free matrix. The aim of this study was to examine this system of repair histologically and to determine, if possible, the components of the system and the mechanisms brought into play. In *Helix aspersa*, a calcifiable matrix is formed from a secreted glycoprotein material, and there is separation in time between the formation of the matrix and its calcification. In these readily available animals, observation and removal of the protein matrix is relatively simple. The possibility that alkaline phosphatase may exert a direct influence upon calcification may be excluded since it is calcium carbonate that is deposited rather than calcium phosphate. A further advantage of using snails is that the matrix contains no phosphatase and no observable fibers.

MATERIALS AND METHODS

Active snails of the species *Helix aspersa* were used. After these snails had been fed for several days, defects were made in their shells. In each instance a piece of shell approximately 1.5 by 0.5 centimeters was removed from the helix adjacent to the visceral hump, the mantle epithelium thus being exposed. After from zero to forty-eight hours, the exposed mantle layer, together with any material secreted onto the surface, was removed by sharp dissection. The removed tissues were immediately fixed by being frozen in isopentane which had been precooled in liquid nitrogen to a temperature of between −150 and −160 degrees centigrade; this was done in order to reduce the mobility of the mineral elements, to avoid alteration of the proteins, and to maintain better morphological detail. Following this treatment, the tissues were dried *in vacuo* at about −30 degrees centigrade.

In one series of snails isotonic sodium citrate was applied to the surface of the defect. A constant pool of the citrate was maintained by fusing a wax box to the surrounding intact shell, and the solution was prevented from flowing under the shell by means of a filter-paper diaphragm.

To demonstrate the presence of cells, the repair membranes of several snails were removed, were stained with toluidine blue without prior fixation, and were then mounted flat and immediately examined.

Embedding and Staining

One series of tissues was embedded in celloidin in order to reduce or eliminate shifting of granules during sectioning and staining. All the others were embedded in paraffin (m.p. 51 degrees centigrade), the embedding being done under partial vacuum at a temperature which never exceeded 57 degrees centigrade. Sections six to eight micra thick were then cut.

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Glycoproteins and glycogen were studied by means of the Hotchkiss method. In this procedure periodic acid was used to oxidize the polysaccharide components into high molecular-weight aldehyde compounds. These compounds combined with leucofuchsin to form a polysubstituted dye compound. The resultant color varied from pale pink to purple-red. Glycogen could be separated from the other Hotchkiss-positive substances in the slides by the use of saliva prior to staining. Some of the sections were incubated in filtered, buffered human saliva for one hour, while others were incubated for the same time in a buffer solution only. According to the Gersh and Catchpole concept of the nature of a ground substance, a pale pink color following use of the Hotchkiss method indicates that the polysaccharide component is more highly polymerized, while more intense col-

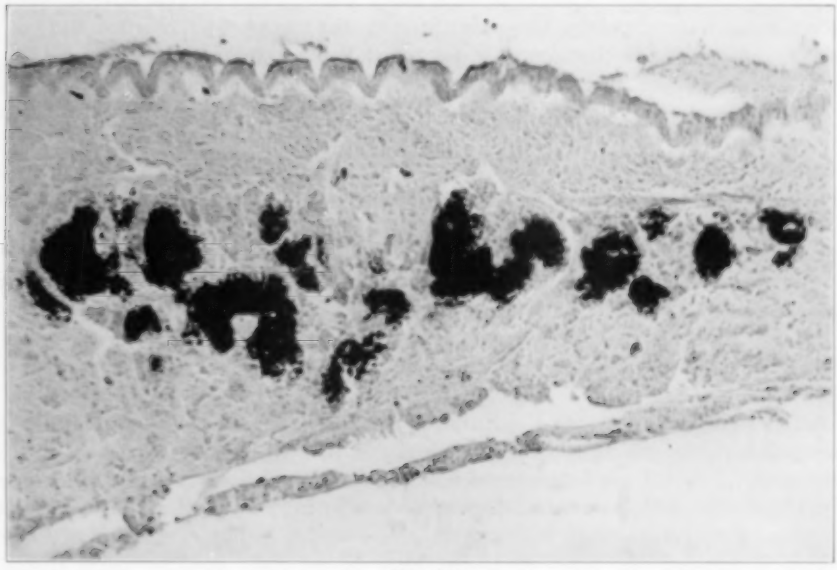

FIG. 1

Photomicrograph (× 260; von Kóssa and eosin) of a section of the mantle showing the general relationship of the epithelium, the subepithelial connective tissue, and the c-cells which are stained black. The tissue was removed before repair had commenced.

oration indicates partial depolymerization or increased concentration of the polysaccharide component.

The presence and location of calcium as carbonate or phosphate was demonstrated by using the von Kóssa staining method as modified by McLean and Bloom. A further modification described by Heller-Steinberg was also used. Areas in which calcium salts have been deposited stain homogeneously black when the method of McLean and Bloom is used, but when the more dilute silver nitrate method is used, gradations of color from yellow to brown or black are found. The interpretation suggested by Heller-Steinberg is that if the staining is brown to tan, crystallized bone salt is present and that if the staining is intensely black, the bone salt is in a more reactive, less crystalline form. When it is in the more reactive form, it can combine more readily with the available silver and so rapidly blackens preferentially.

The technique used for localizing alkaline phosphatase was that described by Gomori. As a control, sodium glycerophosphate was omitted from the incubating solution; in this way, it was possible to distinguish between the sites of enzyme activity and the areas in which the staining was probably caused entirely by the presence of calcium salts.

Foot's staining method [12] was used to demonstrate reticular fibers; in this method, the fibers are impregnated with silver. Sections of guinea pig liver were mounted on the same slides as the snail tissue and were also stained. This was done to indicate the efficiency of the reticular-staining procedure.

Sections were stained with toluidine blue at pH 3.0. To investigate further the cytoplasmic basophilia observed in the mantle epithelium, sections which had been previously incubated with ribonuclease for half an hour at 23 degrees centigrade with distilled-water controls were also stained.

Detailed morphological studies were also made on sections stained with hematoxylin and eosin.

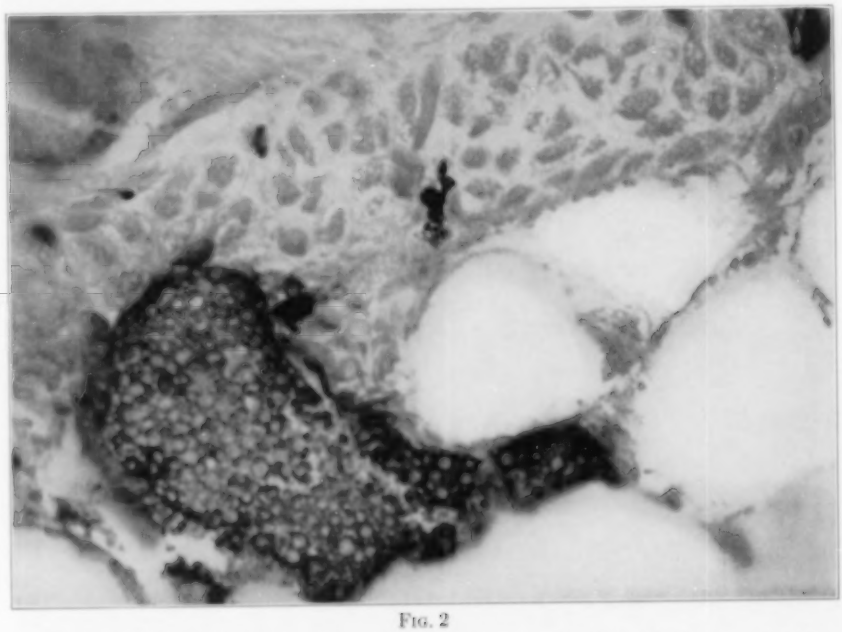

FIG. 2

Photomicrograph (× 1125; hematoxylin and eosin) of a section of mantle tissue removed immediately after the shell defect had been made. A c-cell is apparent in the deeper connective tissue. The granules within this cell are stained deeply only at their peripheries. Three unstained g-cells are visible to the right of the c-cell.

Some unstained deparaffined sections about twenty micra thick were observed microscopically (at low power) while dilute acid was applied. This was done to observe the effect of the acid on certain of the tissue cells which contained calcium salts, presumed to be calcium carbonate. The formation of gas bubbles, coincident with the dissolution of the crystals in these cells, showed that the cells were composed of calcium carbonate rather than of calcium phosphate.

RESULTS

The Mantle

Since repair of the shell defect is carried out by the mantle layer, it was desirable to examine the appearance and structure of this layer before repair began.

The surface of the mantle is covered by a layer of simple columnar or cuboidal epithelium (Fig. 1). In each cell in this layer there is a basally placed nucleus with a chromatin network; this nucleus usually also has a well defined nucleolus. The cytoplasm contains yellow-brown pigment granules which are seen mainly in the supranuclear area.

Beneath the epithelium is a basement membrane; this membrane is continuous with the underlying connective tissue, which may contain muscle fibers, fibroblasts, and small amoebocytes. Immediately beneath the connective tissue are the cells which are especially characteristic of the mantle and which are apparently important in the repair process.

Calcium Cells and Glycogen Cells

The outstanding feature of the deeper layers of the connective tissue of the mantle is the presence of two types of large cells. One of these two types is characterized by its content of calcium carbonate; the cells of this type will be referred to as calcium cells or

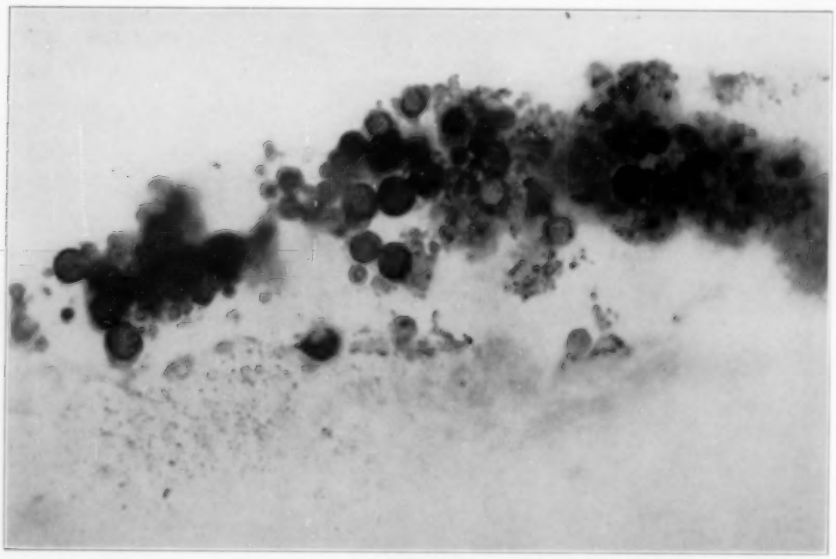

FIG. 3

Photomicrograph (× 1125; Heller-Steinberg method) of a section of tissue removed at the time the defect was made. Most of the granules in the c-cell shown in this section are stained black at their peripheries and brown at their centers.

c-cells. The other type of cell is densely packed with glycogen; cells of this type will be designated as glycogen cells or g-cells. Less prominent, but also found in the same area, are small amoebocytes and large cells containing pigment.

The c-cells (Figs. 1 and 2) are best seen when the sections are treated with 2 per cent silver nitrate. When so treated, silver substitutes for the calcium of the calcium carbonate, and when subsequently reduced by light, it appears either black or a more or less deep shade of brown in sections. The c-cells contain large intracytoplasmic granules. These granules, within which the calcium carbonate is located, show considerable variation in their staining reaction to the Heller-Steinberg method (Fig. 3).

When the tissues are treated by the Hotchkiss method, the reactions of the g-cells, which are located in the same general area as the c-cells, are particularly interesting. These cells are seen to be densely packed with deep purple-red-stained glycogen, are clearly distinct from the c-cells, and are usually present in considerable numbers (Fig. 4). If the sections are incubated in saliva before staining, the glycogen is removed and the g-cells are seen to contain a small number of Hotchkiss-stainable granules (Figs. 5 and 6).

Other Staining Reactions

Following use of the Hotchkiss procedure the brush border of the epithelial cells

appears intensely red and granules of glycogen are often seen in the basal part of the cells (Figs. 7 and 8). The pigment granules of the epithelium are also stained by the Hotchkiss method, but there is some suggestion that more granules are seen in the stained cells than are seen in comparable cells viewed unstained. If the stained or unstained sections are viewed in the interference microscope, two types of granules are seen in the supranuclear area. One type corresponds to the pigment granules and the other may represent secretory granules.

An interesting result of staining with toluidine blue is the basophilic reaction of the

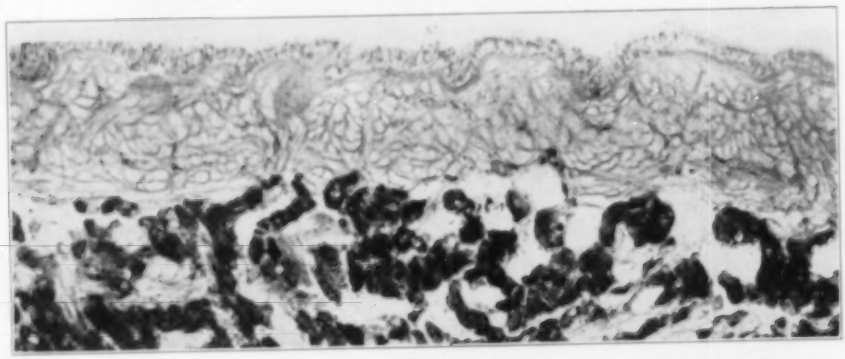

FIG. 4

Photomicrograph (× 245; Hotchkiss method) of a section of mantle tissue removed before repair had commenced. The glycogen of the g-cells is stained purple-red.

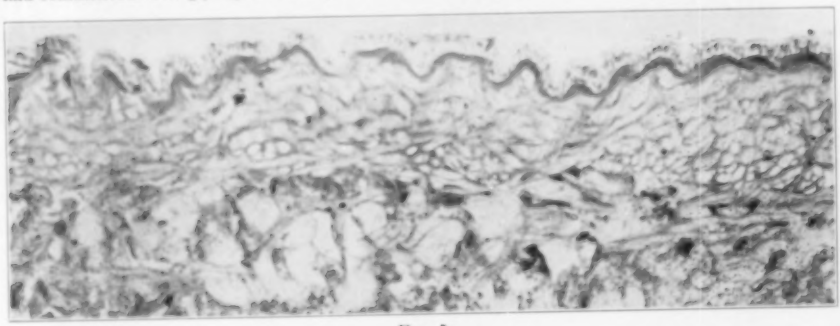

FIG. 5

Photomicrograph (× 245; Hotchkiss method) of a section which is similar to the one in Fig. 4, except that the tissue was incubated in saliva before staining. The g-cells have lost their glycogen and are pale in color.

epithelial cytoplasm. The basophilia appears more intense in the perinuclear cytoplasm (Fig. 9), but is absent if the tissue has been incubated in ribonuclease before it is stained (Fig. 10).

The outer surface of the mantle epithelium is stained black when treated by the Gomori method for alkaline phosphatase (Figs. 11 and 12). The c-cell granules are likewise stained black, but since they also appear black when sodium glycerophosphate is omitted from the incubation mixture in the control sections (Figs. 13 and 14), this does not demonstrate that they contain phosphatase.

The Repair Membrane

Soon after a defect has been made in the shell of a snail, a clear watery fluid can be seen grossly on the exposed surface of the soft tissues. This fluid soon becomes more viscous. With time more material is secreted and eventually this material becomes a mem-

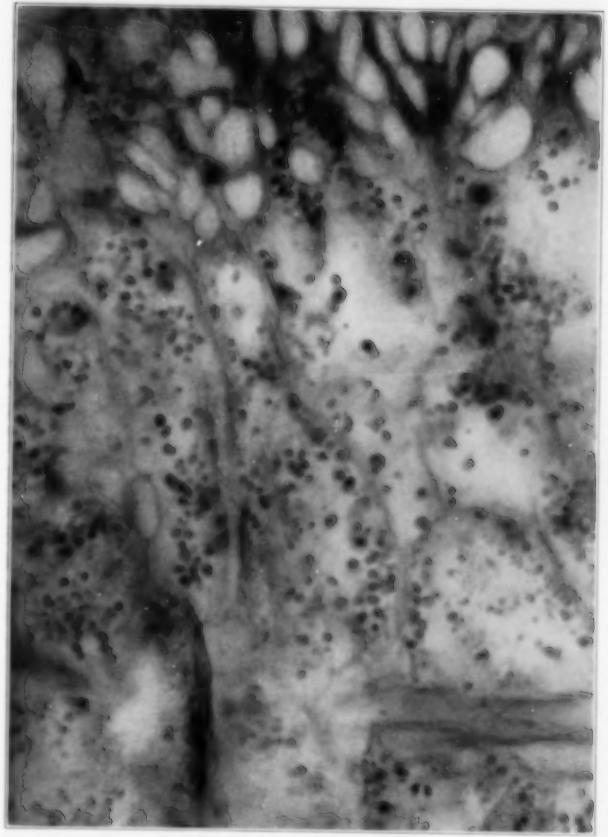

FIG. 6

High-power photomicrograph (× 1125; Hotchkiss method) of the section shown in Fig. 5. Hotchkiss-positive granules are apparent within the g-cells following digestion of the glycogen.

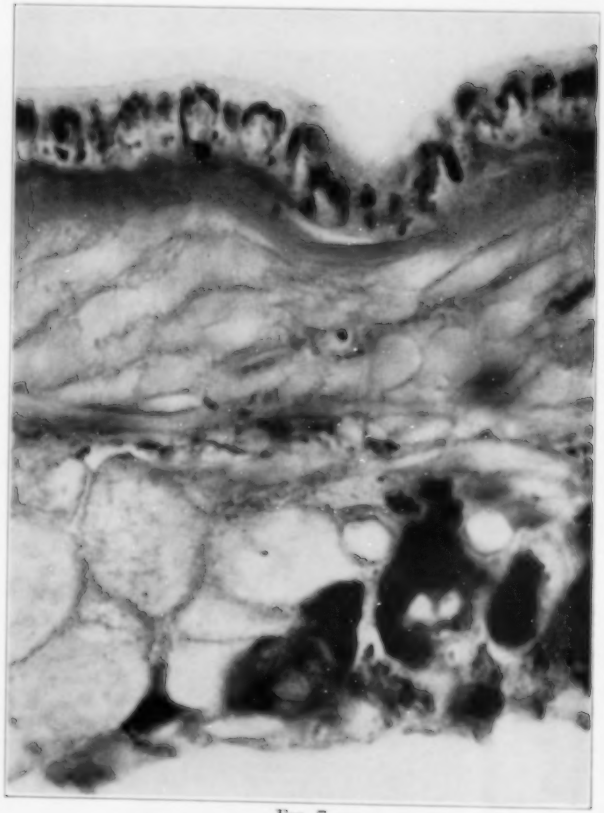

FIG. 7

Photomicrograph (× 1125; Hotchkiss method) of a section of mantle tissue removed before repair had commenced. Particles of glycogen are visible in the basal part of the epithelial cells. The smaller granules, which appear mostly in the supranuclear area, are pigment. The glycogen of the g-cells is intensely stained, but the c-cells in the lower left of the picture contain little Hotchkiss-stainable material.

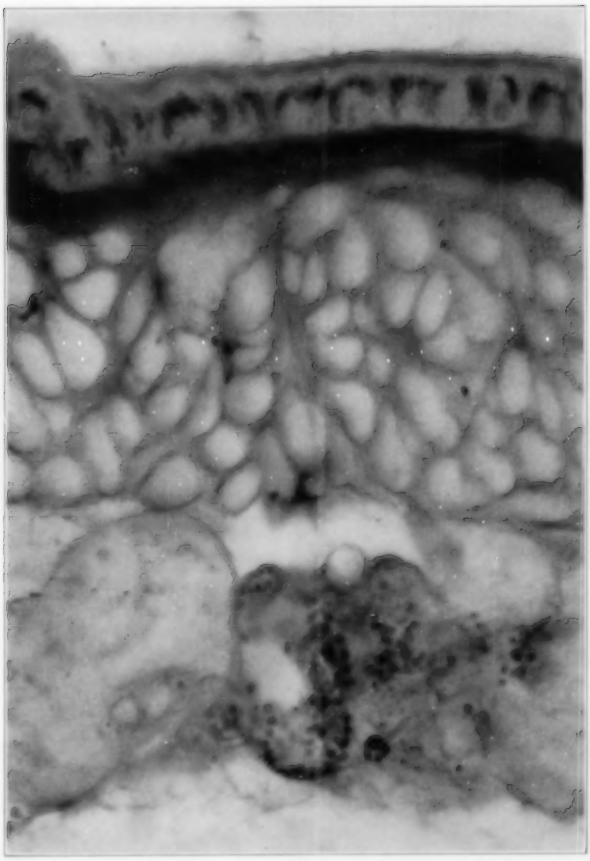

FIG. 8

Photomicrograph (× 1125; Hotchkiss method) of a section taken from the same tissue as the section shown in Fig. 7; this section was incubated in saliva before staining. The particles of glycogen have been removed from the g-cells and the epithelium. Hotchkiss-positive granules remain in the g-cells, and the pigment granules can be seen in the epithelium.

brane with a dry surface which begins to calcify (Fig. 15). Six to ten hours after repair has begun, crystalline calcium salts appear in the outer surface of the membrane. When the dilute-silver-nitrate method of Heller-Steinberg is used, these crystals are not stained except at their peripheries, which usually appear pale yellow. With 2 per cent silver nitrate the crystals stain black, and with hematoxylin they stain blue.

Before the fully formed repair membrane becomes extensively calcified, two distinct zones are evident. In the early stages of its development the membrane appears fibrous after being treated by freezing and drying (Fig. 16), is basophilic, and stains purple or pink when treated by the Hotchkiss method. The fibrous appearance of the membrane is probably in part the result of the formation, during freezing, of ice crystals in the watery material which is homogeneous when first secreted immediately after injury to the shell. After repair has proceeded for several hours, there is an abrupt transformation of the outer layer of the fibrous membrane into a more dense form, with beginning calcification at the outer surface (Fig. 17). The transformed tissue is eosinophilic and stains red with the Hotchkiss method. This change in structure seems to progress until the mem-

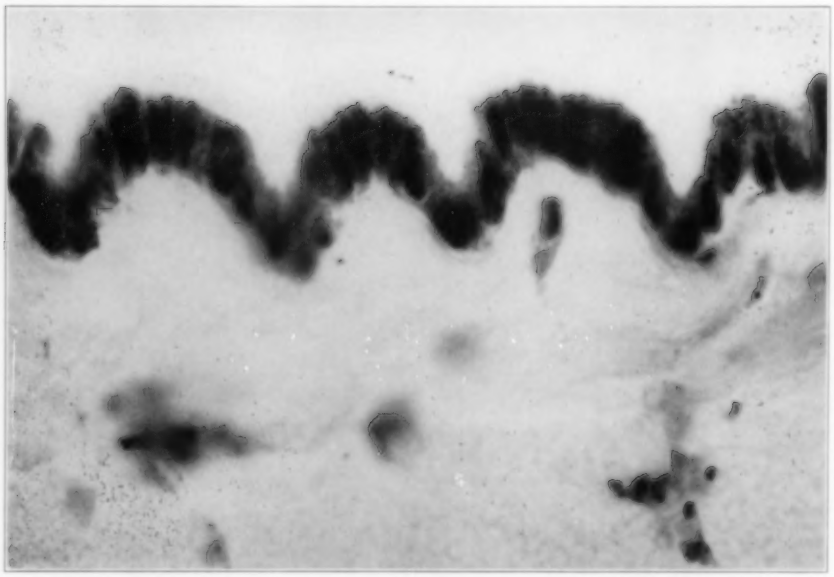

FIG. 9

Photomicrograph (× 1125; toluidine blue) of a section of mantle tissue removed immediately after the shell defect was made. There is intense basophilia in the epithelial cytoplasm, and the nuclei are stained densely.

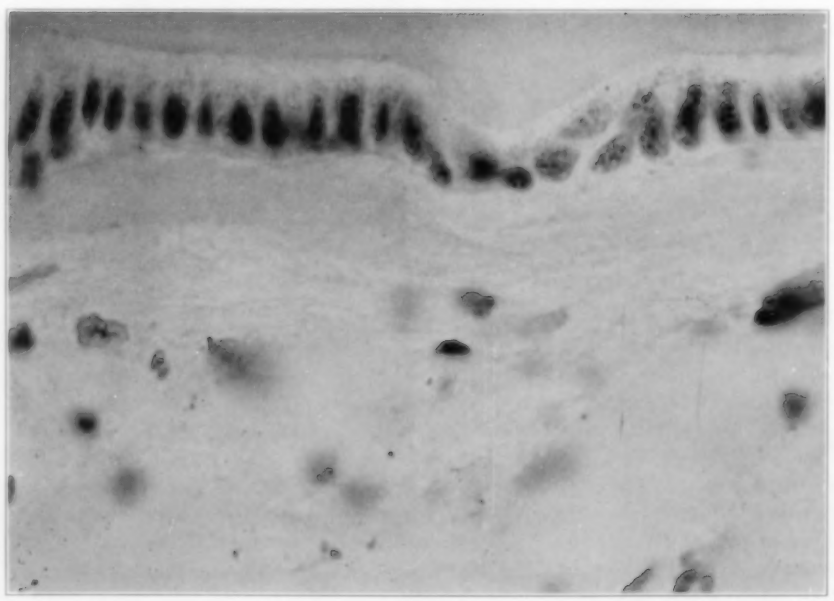

FIG. 10

Photomicrograph (× 1125; toluidine blue) of a section taken from the same tissue as the section shown in Fig. 9; this section was incubated in ribonuclease before staining. The basophilia of the epithelial cytoplasm is no longer evident. Pigment granules can be seen around the nuclei, and with the microscope it is evident that all the epithelial cells stain similarly.

brane appears homogeneous after being treated by freezing and drying; at this time it stains intensely red when treated by the Hotchkiss method.

Before becoming extensively calcified the outer layer of the fibrous repair membrane shows a green metachromasia when treated with toluidine blue, while the inner layer remains unstained. The repair membrane is not stained when treated by the Gomori method for alkaline phosphatase. Small amoebocytes containing glycogen are seen in some parts of the fibrous layer of the repair membrane, but are rarely seen in the outer layer. Examination of unfixed membranes spread flat and stained on a slide generally confirms this

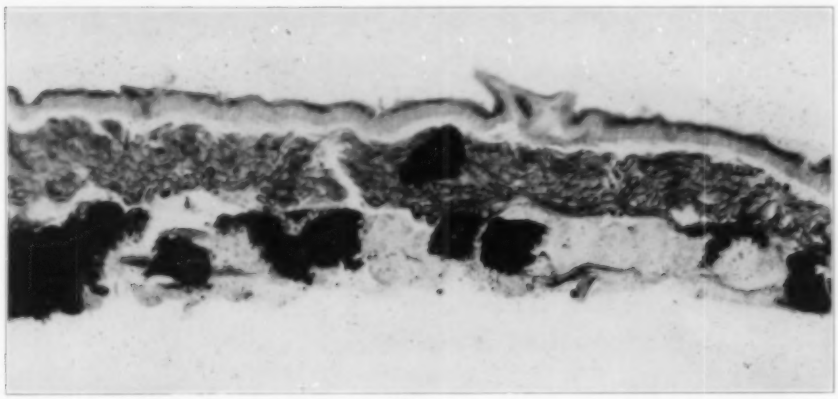

FIG. 11

Photomicrograph (× 260; Gomori method) of the mantle layer showing the reaction of the tissue following staining for alkaline phosphatase. In the epithelium the stain is localized almost entirely along the free border of the cells. The basement membrane is not stained. The e-cells are stained black, but this is not significant since they are also stained in the control section shown in Fig. 13.

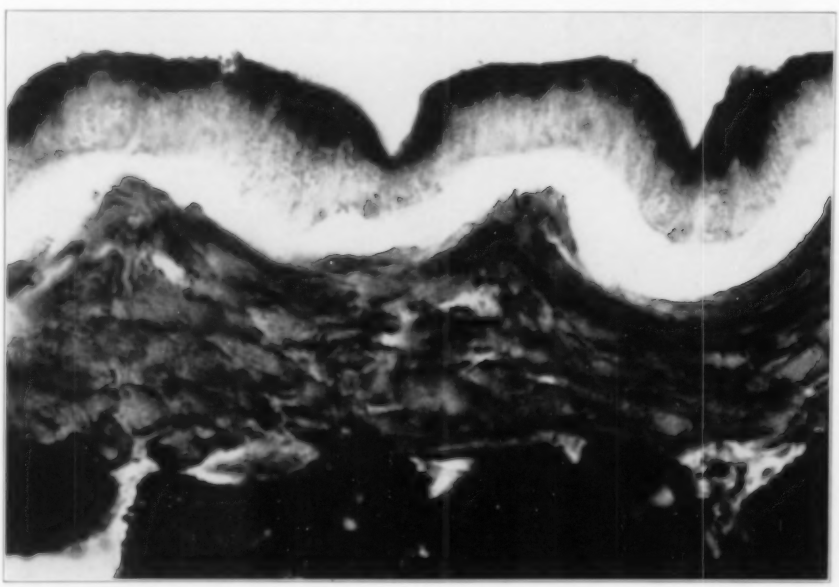

FIG. 12

High-power photomicrograph (× 950; Gomori method) of the section in Fig. 11 showing the epithelium and subjacent tissue.

observation, although it also shows that large areas are free of these cells. Cells are usually seen underneath and along cracks in the calcified repair membrane.

In the earlier stages of repair, the intracytoplasmic granules of the c-cells stain black at their peripheries and yellowish-brown at their centers when treated by the Heller-Steinberg silver method. As repair proceeds, some of these granules are stained homo-

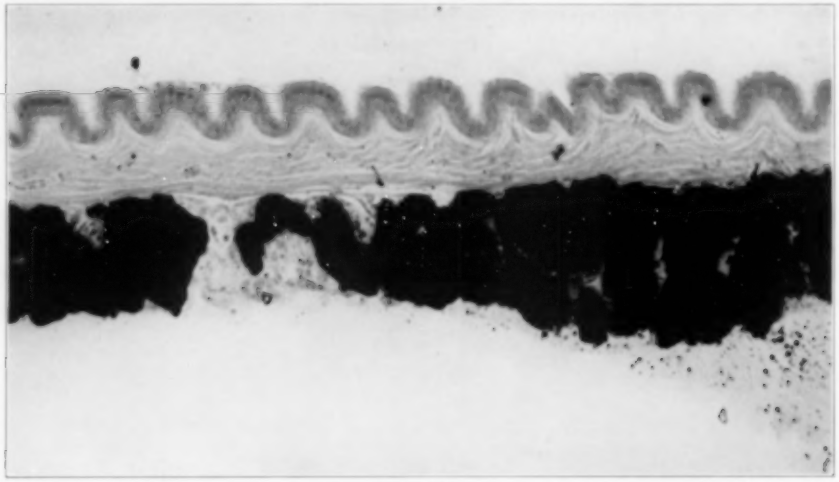

FIG. 13

Photomicrograph (× 260; Gomori method) of a control section taken from the same tissue as the sections in Figs. 11 and 12; this section was treated as for alkaline phosphatase except that sodium glycerophosphate was omitted in the incubation mixture. The granules of calcium carbonate in the c-cells are heavily stained, indicating that the staining in the two previous figures does not necessarily indicate the presence of phosphatase.

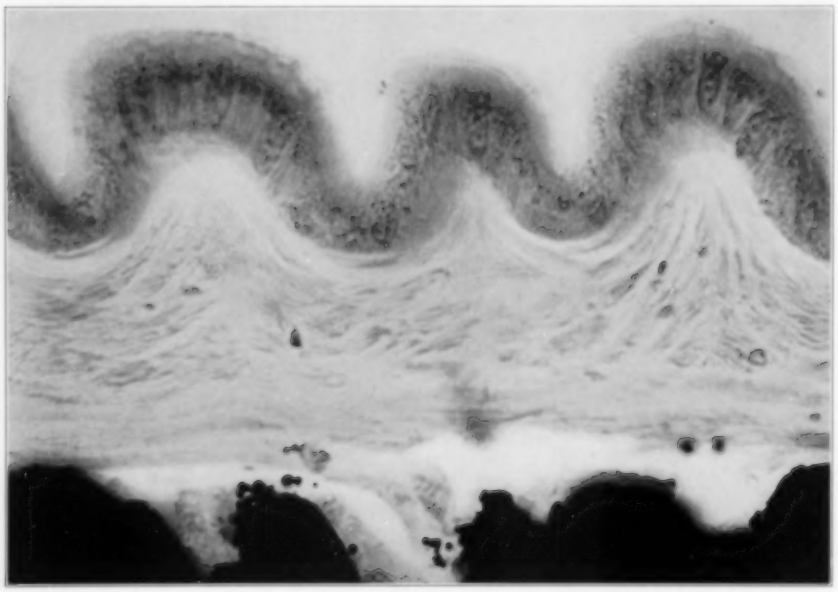

FIG. 14

High-power photomicrograph (× 950; Gomori method) of the section in Fig. 13 showing the epithelium and subjacent tissue.

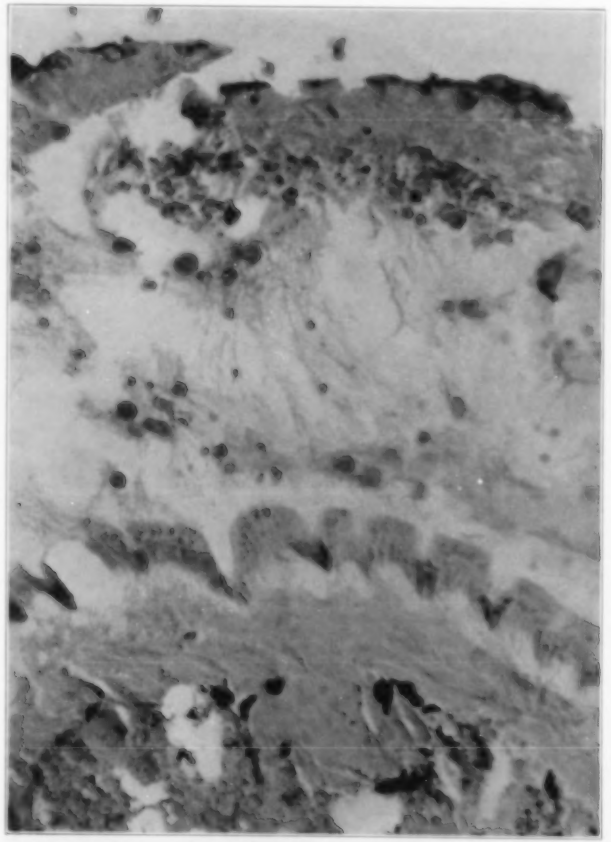

FIG. 15

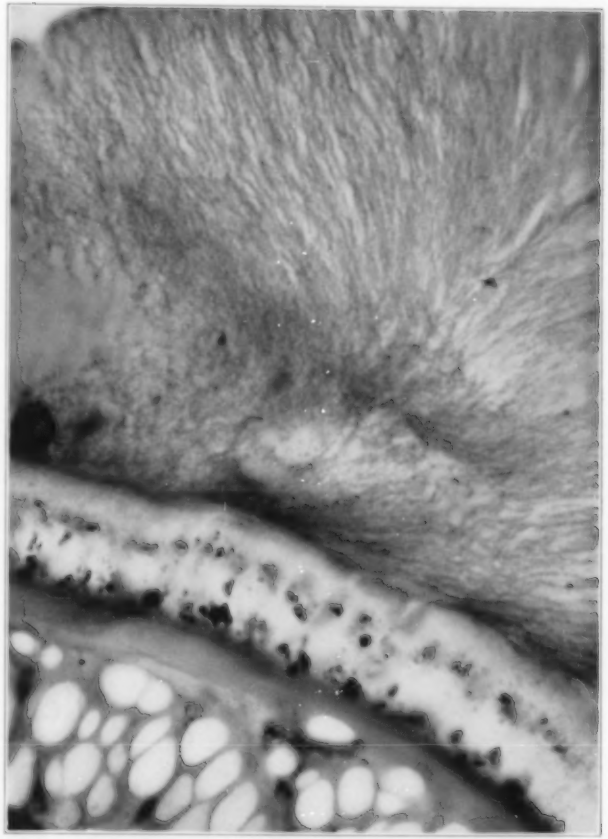

FIG. 16

Fig. 15: Photomicrograph (× 335; hematoxylin and eosin) showing part of the mantle layer and secreted repair membrane eighteen hours after a defect was made. The two zones of the repair membrane are evident. The inner zone is fibrous and the denser outer zone shows beginning calcification at its peripheral surface. Beneath the mantle epithelium is a layer of connective tissue, under which the c-cells, g-cells, and pigment cells are located.

Fig. 16: Photomicrograph (× 1000; Hotchkiss method) of the inner part of the repair membrane and the underlying tissue twenty hours after the defect was made. The fibrous appearance is evident.

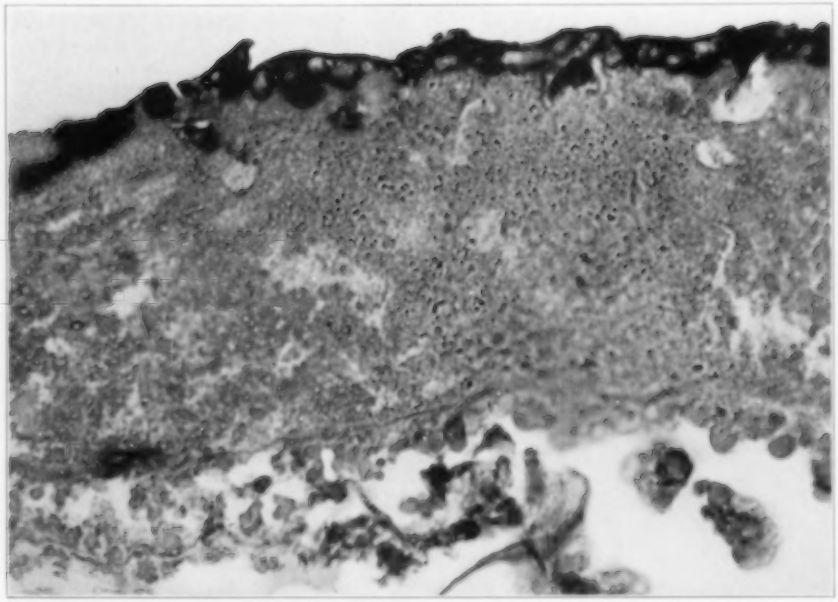

FIG. 17

Photomicrograph (× 1125; hematoxylin and eosin) of the outer part of the repair membrane, showing its more dense non-fibrous structure twenty-four hours after the shell defect was made. Beginning calcification is evident at the outer surface.

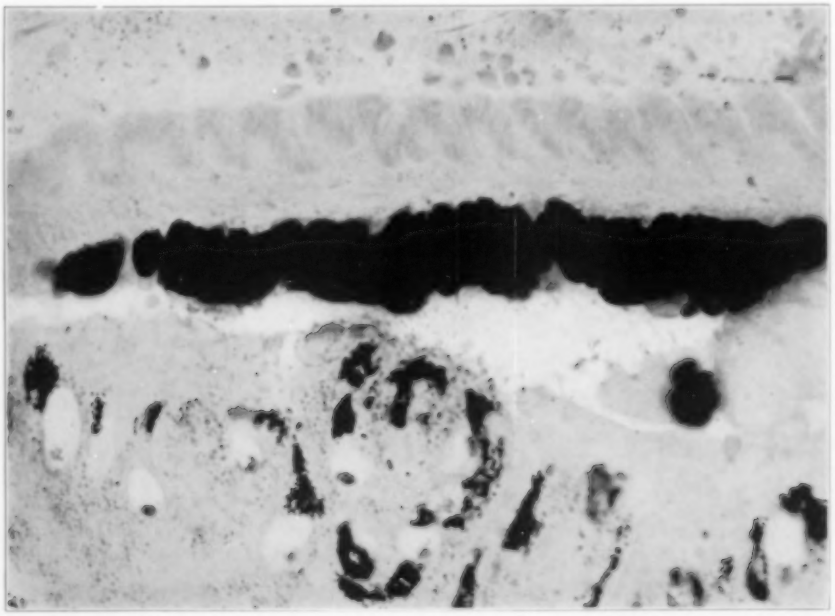

FIG. 18

Photomicrograph (× 260; Heller-Steinberg method) of a section of the mantle of a snail sixteen hours after the defect had been made. After eight hours of undisturbed repair the defect had been covered with sodium citrate solution for a further eight hours. The granules within the c-cells are stained homogeneously black.

geneously black, while others are stained black only in the very center. In general, there is a tendency for the centers of the granules to stain more darkly brown to black as repair advances.

The appearance of the c-cells in animals which have been treated with citrate during attempted repair is most striking following staining by the dilute-silver-nitrate method (Fig. 18). The granules become homogeneously black and so intensely stained that it is difficult to identify individual granules. Treatment of the citrated material by the McLean and Bloom silver method, requiring immersion of the tissue in aqueous solutions for a total of more than three hours, results in almost complete leaching of the calcium salts.

DISCUSSION

Although shell formation and repair in molluscs has been studied extensively since the eighteenth century, many aspects of the problem still remain unsolved. The histological findings are in general consistent, but their interpretation varies widely [2,18,21,23]. Wagge and Mittler, after studying the repair of shell defects in seventeen different species of British land snails, concluded that the process is essentially the same in all the species studied. With some qualifications they extended this statement to include marine molluscs. In marine molluscs repair is slow [1]; furthermore, it may fail unless an artificial cover is placed over the shell defect during repair in order to isolate the area from the surrounding water. Other workers investigating the problem in individual species have confirmed the conclusion of Wagge and Mittler that repair of the shell is essentially the same in all molluscs. In general it seems agreed [2,21] that the main characteristics of shell repair are the formation of a protein membrane and the deposition of calcium carbonate in this membrane.

The observations made in the present study confirm these findings and add further information concerning the mechanisms involved. A glycoprotein matrix, secreted by the epithelial cells of the mantle, is deposited into the shell defect. This matrix has no demonstrable fibers, contains few cells, and is not stained when the Gomori method for alkaline phosphatase is used. When first secreted, the matrix is not calcifiable and, after freezing and drying, is quite water soluble. Later it becomes calcifiable and is more dense and less water soluble following freezing and drying. This change is apparently brought about by loss of water and by concomitant changes in the glycoprotein. Calcification is first apparent on the outer surface of the matrix where calcium carbonate is deposited. The calcium carbonate appears to be mobilized from large cells (c-cells) packed with spherules of calcium carbonate and located subjacent to the subepithelial connective tissue.

Source of the Repair Membrane

The actual source of the repair membrane and of the organic matrix found in normal shell thickening has been a matter of some controversy [21]. Most investigators have felt that the organic matrix in normal shell thickening is secreted by the epithelial cells [2,3,7,8,21]. Wagge [24] believed that shell repair and normal shell growth are quite different processes. He stated that the mantle epithelium is not involved in the secretion of the protein repair matrix, but that amoebocytes, having migrated onto the exposed surface, secrete and calcify this matrix.

The material reported in this paper is interpreted as indicating that the repair matrix is secreted by the mantle epithelial cells. The c-cells (type-B amoebocytes of Wagge [24]) are never found on the surface of the mantle, while the small amoebocytes (type-A of Wagge [24]), although seen occasionally on the mantle surface, do not seem to participate in the process of repair. The small amoebocytes are found usually in locations in which irritation of the underlying soft tissue is most likely to occur, such as along breaks in the partially calcified repair membrane. These cells contain glycogen, but not stainable calcium. In many of the sections studied the newly secreted matrix appeared to be continuous with the outer

surface of the epithelial cells and observations of the staining characteristics of these cells during the repair process indicated that they elaborate and secrete the repair matrix.

Phosphatase

When the Gomori method was used, alkaline phosphatase was always demonstrated at the peripheral border of the epithelial cells. This finding is similar to that reported for marine molluscs by Bevelander and Benzer [2, 3], but differs from that reported for *Helix aspersa* by Wagge [24], who found no phosphatase in the mantle epithelium following staining by the Gomori method.

It is possible that phosphatase is involved in protein elaboration and secretion; certainly there is a growing amount of evidence in support of this view [4, 11]. A close association between the presence of mucopolysaccharide and a high level of phosphatase activity has been reported by Moog and Wenger. The staining reactions of the mantle epithelial cells reported here closely resemble the reactions described in the literature for cells involved in protein elaboration and secretion. The distribution of phosphatase and ribonucleic acid in the mantle epithelial cells of the snail is similar to that found in the silk glands of the spider [4] and in ameloblasts [27].

Caspersson stated that in cells of many types there is a high level of nucleic acid during protein synthesis. Bradfield, on the basis of his studies of the silk glands of spiders and silkworms, suggested that phosphatase may be involved in the process which liberates the newly formed protein from its combination with nucleic acid; he provided no direct evidence for this theory, however. The rather striking similarity between the staining reactions of cells known to secrete protein and the reactions of epithelial cells as seen in the repair process in the snail supports the view that the mantle epithelial cells are responsible for the formation and secretion of the glycoprotein repair matrix.

Glycogen, Phosphorylase, and Glycoprotein

Small particles of glycogen were found in most of the epithelial cells either before or during the early stages of secretion of the repair matrix; these particles were in the cytoplasm basal to the nucleus. Other workers have reported similar findings for different tissues [6, 9, 15]. Cobb described an inverse relationship between the glycogen content of bone and cartilage cells and the activity of phosphorylase. Cells most consistently showing phosphorylase activity were found in areas of rapid matrix-glycoprotein formation, suggesting that there may be some relationship between the consumption of glycogen by phosphorylase and the production of bone matrix. No tests for phosphorylase were made in the present investigation.

The Hotchkiss Procedure

In this study the calcifiability of the glycoprotein matrix was investigated chiefly by the use of the Hotchkiss stain. This procedure is considered specific for glycoprotein, provided that adequate controls are used. It is clear, however, that the state, or change of state, of the ground substance, as indicated by the Hotchkiss stain, is not a specific criterion of calcifiability or calcification, since similar staining reactions can be observed in non-calcifiable tissues.

The outer part of the repair membrane in which calcification may occur stains intensely when treated by the Hotchkiss procedure—unless calcium has already been deposited, in which case there is little or no staining. Similar reactions have been described for other tissues, and there appears to be some relationship between reaction to the Hotchkiss stain and calcifiability or calcification. Heller-Steinberg, after studying the bones of rats treated with parathyroid extract, reported a correlation between changes in the glycoprotein ground substance, as indicated by the Hotchkiss stain, and the degree of calcification. Cobb, who used the same stain in studies of normal bone, described a cor-

relation between a highly stainable matrix and a light deposition of calcium salts, but reported that a highly calcified matrix stains palely or not at all. Engel [19] reported similar findings for dentin.

Gersh and Catchpole interpreted the Hotchkiss stain as indicating the degree of polymerization of the ground substance, which they related to calcifiability. They stated that the matrix may become calcifiable when the degree of polymerization is at a certain level and that partially depolymerized chondroitin sulphate or other polysaccharide complexes contain many reactive groups, some of which may react with calcium. They added that complete depolymerization would probably be ineffectual. According to their concept, the matrix is relatively unpolymerized when it is first secreted, as is shown by staining of the repair membrane by the Hotchkiss method. Polymerization progresses to the point where the matrix becomes calcifiable; following calcification the matrix is in a highly polymerized state.

The portion of the repair matrix which is in the transition zone between the calcified and non-calcified areas stains more intensely by the Hotchkiss method than does the surrounding non-calcified portion of the matrix.

Metachromasia

The green metachromasia seen in the outer part of the repair membrane after staining with toluidine blue is intensified in the zone which is deeply stained by the Hotchkiss method. The calcified matrix is not metachromatic. Wislocki and Sognnaes reported that green metachromasia was observed when recently formed enamel matrix was stained with toluidine blue. Rubin and Howard stated that all known acid mucopolysaccharides stain metachromatically red and are strongly Hotchkiss-positive. They believed that these staining reactions indicate a change of state or of concentration of the acid mucopolysaccharides and that this change is related to the initiation of calcification.

Source of Calcium

The source of the calcium deposited in the repair membrane is a matter of some dispute [21, 23]. Sioli, in his analysis of all the tissues of the snail, found that there is not enough calcium in the soft tissues to calcify the repair membrane. He concluded that calcium must be mobilized from the shell. At no time during the repair process did he find an increased concentration of calcium in the blood. Wagge [25] reported that the amount of calcium deposited in the repair membrane can be varied by changing the dietary intake of calcium. It would appear, then, that calcium mobilization from the shell is a slow process and that the dietary intake of calcium is an important factor in shell repair. Robertson stated that calcium is separated from the blood by cells at the mantle edge and is then secreted in colloidal form between the mantle and the periostracum. It has been stated [24, 25, 26] that amoebocytes absorb calcium from the "lime" cells of the digestive organ and transport it to the site of shell repair, where they secrete both the calcium and the organic matrix.

In the present study there were indications that calcium is mobilized from the c-cells during repair of a shell defect. Before repair had begun, the calcium carbonate granules in these cells stained black at their peripheries and brown at their centers when the Heller-Steinberg silver stain was applied. According to the explanation offered by Heller-Steinberg, black staining indicates that the salts are in a relatively reactive state. As repair proceeded, there was a tendency for the granules to stain more homogeneously black, which was interpreted as indicating that the calcium salts were becoming more reactive. As a further test of this interpretation, repair was allowed to proceed while the mantle surface of the defect was bathed in isotonic sodium citrate for various lengths of time. The greatly increased staining of the granules after this procedure indicated that the calcium

was being mobilized. The citrate binds calcium in a soluble non-ionic form and thereby reduces the ionic concentration of calcium in the tissue fluids. To restore the concentration to a normal level, calcium is apparently mobilized from the c-cells. After treatment with sodium citrate, the calcium in the granules was much more soluble than previously; prolonged immersion in water dissolved it so that the c-cells were no longer stainable by the silver nitrate methods.

It appears that in shell repair the matrix has a special affinity for the mineral constituent of the shell, which in molluscs is calcium carbonate. Why calcium carbonate is deposited instead of calcium phosphate is not known. These studies added nothing to the solution of this problem except the knowledge that alkaline phosphatase is present in the epithelial cells in abundance during the time that calcium carbonate, rather than phosphate, is being laid down. This is evidence for the view that the function of phosphatase has to do with the formation of a calcifiable matrix rather than with the calcification process itself.

In any event the calcium which exists in a solid form within the c-cell granules is mobilized and transferred across the mantle epithelium to the newly secreted matrix. In the snail the presence of calcium has not been demonstrated in the epithelium or in the remaining tissue of the zone between the c-cells and the calcifying repair membrane. Bevelander [2], who used radioactive calcium in his study of normal calcification in marine molluscs, concluded that in the mollusc ionic calcium can be and is utilized in the formation of the calcified shell. By means of autoradiograms he found that the radioactive calcium was located predominantly at the periphery of the mantle, below and in the region of the epithelium.

At the time that calcification is beginning in the outer zone of the repair membrane, the total membrane is about 100 micra thick and the inner and outer zones are about equal in thickness. The total distance from the c-cells to the calcifying part of the membrane at this time is about 150 to 200 micra. Because of this spatial separation of the source of the calcium, the pre-calcifiable matrix, and the calcifiable matrix and because the calcium deposited can come only by way of the mantle, it seems that the terrestrial snail is a suitable laboratory animal for investigation of the problems of calcium transport. The changes in the ground substance of the matrix as the matrix becomes calcifiable may also be studied.

SUMMARY

Findings of this study of the repair of a shell defect in the snail *Helix aspersa* are as follows:

1. The defect is filled by a glycoprotein matrix.
2. The mantle epithelial cells show changes which indicate that these cells secrete the glycoprotein matrix.
3. The matrix contains no demonstrable reticular fibers and few cells. Phosphatase, demonstrable by the Gomori method, is absent.
4. Coincidental with the formation of the matrix there is a high concentration of ribonucleic acid in the epithelial cells.
5. After secretion, the organization of the matrix changes so that it becomes less water soluble, more dense, and more calcifiable. It also stains intensely with the Hotchkiss stain, and when stained with toluidine blue, shows a green metachromasia.
6. Calcification commences at the outer surface of the matrix and proceeds inward toward the epithelium.
7. Calcium deposited in the repair membrane seems to be mobilized from large cells which contain calcium carbonate.

NOTE: I wish to thank Dr. Isidore Gersh of the Department of Anatomy and Dr. Franklin C. McLean of the Department of Physiology for their advice and assistance.

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Ultrasonic Energy and Surgically Produced Defects in Bone*

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The report by Bender and his associates of osteogenesis in normal bone of dogs after exposure to ultrasonic energy led to the question of potential improvement in the healing of fractures as a result of such exposure. Several European workers have studied this problem, arriving at conflicting conclusions.

Maintz found that healing of fractures in rabbits was not stimulated by small amounts of ultrasound. Larger doses actually delayed healing but caused osteogenesis at a distance from the site of the fracture and ultrasonic application. He concluded that periosteal new bone could be produced by ultrasonic energy, but only in intact normal bone, and that the required dose was close to the destructive level, so that this formation of new bone often was followed by atrophy of bone, with and without fractures. It was his opinion that therapeutic doses in human patients resulted in no changes in bone and that further investigation was indicated regarding the application of this osteogenic capacity to fractures in human patients.

De Nunno reported stimulation of osteogenesis in femoral fractures of rabbits as a result of ultrasonic exposure consisting of smaller doses than those used by Maintz.

Murolo and Claudio studied fractures in guinea pigs exposed to pulsed ultrasonic energy and enthusiastically concluded that definite acceleration in the reparative process was produced by this agent and technique.

We wished to study this problem further. Because of the difficulty in producing a series of uniform fractures of the type seen clinically and in order to have a standard form of initial damage, a defect of the window type was chosen as a substitute for the fractures used in the experiments described.

MATERIALS AND METHODS

The Siemens Sonostat generator with a frequency of 800 kilocycles and a sound head with a radiating surface of ten square centimeters were used in all cases. The mode of action of this equipment has been described in a previous paper [1].

Surgical Technique

With the animals under anaesthesia induced by the intravenous injection of pentobarbital (one-quarter grain per five pounds of body weight) and by means of standard surgical preparation and aseptic techniques, a large half-moon incision with its convexity directed posteriorly was made on the lateral aspect of the shaved right thigh of dogs. The extremes of this incision were about nine centimeters apart and lay directly over the knee distally and over the upper part of the femoral shaft proximally. The purpose of this type of incision was to avoid the irregularity of a recently sutured cutaneous incision which would result in poor coupling of the sound head and the skin. The flap of skin was turned back anteriorly, exposing the fascia lata, which was then incised along the axis of the shaft. The space between the vastus lateralis and the biceps femoris was enlarged to expose the shaft of the femur; and the periosteum was incised longitudinally and retracted. With the aid of dividers and a special metallic template containing holes for guides, three holes were drilled in the lateral femoral cortex at a standard distance above the lateral femoral condyle. Sponges moistened in an isotonic solution of sodium chloride were packed around the bone to diminish the

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† The Mayo Foundation, Rochester, Minnesota, is a part of the Graduate School of the University of Minnesota.

scattering of bone dust in the tissues. The template was then removed and a rectangular defect was made by cutting out the bridges of bone between the holes with an osteotome.

Efforts were made to avoid injury to the marrow, but this structure occasionally was disrupted in attempts to remove all of the chips of bone. In closure of the wound, the periosteum was not sutured over the defect but the remainder of the wound was closed in two layers.

The same procedure was repeated on the left femur, except that a short straight cutaneous incision directly over the bone was used because the sound head was not to be applied to this side.

This operation resulted in a rectangular window in each lateral femoral cortex measuring 0.35 by 1.8 centimeters. This size was believed to be adequate for roentgenographic follow-up without dangerously weakening the shaft itself.

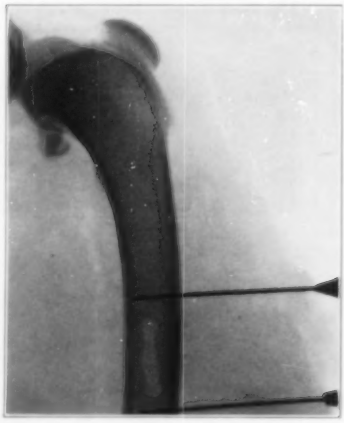

FIG. 1

Control roentgenogram made before exposure to ultrasonic energy showing a needle thermocouple at each end of the defect.

Method of Ultrasonic Exposure

Two needle thermocouples were inserted through the anterior part of the thigh in such a way that they lay laterally in the periosteal tissues but were in contact with the bone at each end of the defect; by use of these thermocouples, the response of a galvanometer during each massaging excursion of the sound head indicated roughly whether or not the ultrasonic energy was reaching the defect accurately. Roentgenograms were made to check the position of these needles after their insertion (Fig. 1). The interval between operation and exposure to ultrasound varied from about fifteen minutes to two hours.

The shaved lateral aspect of the right thigh of each dog was exposed to varying amounts of ultrasonic energy for three periods of five minutes each, with a five-minute interval between exposures for cooling. A massaging application of continuous energy was used, the excursions being directed along the axis of the femoral shaft. An ample film of mineral oil was used as a coupling medium. The left femur in each animal served as a control.

Sixty-seven adult dogs were used. Four groups of sixteen dogs each were exposed to the same dose of ultrasonic power, namely, ten, fifteen, twenty, and twenty-five watts of total output. The remaining three dogs were exposed to five watts of power.

Bender's group reported that an increase in temperature of more than 7 degrees centigrade was necessary in their series before osteogenesis occurred. For this reason, the sound head was held stationary above each thermocouple until this basic increase in temperature was reached before the timed five-minute massaging exposure was begun. Efforts were then made to increase the temperature at each thermocouple in stepwise fashion to a maximum degree and at the same time to keep the readings at each end of the defect comparable.

The time required to obtain the basic increase in temperature varied not only with different doses but also within each dosage group. This resulted in great variation in the total energy applied to the thigh as a whole. However, since the thermocouple guides were in contact with the bone to be exposed and in view of the difficulty of locating these thermocouples (and therefore the bone beneath them) with consistent accuracy by means of the sound field, this variation in duration of exposure was not believed to be as significant as it would first appear to be in relation to the estimated energy striking the bone. This re-emphasized the difficulty in the accurate location of deeply situated targets with the sound field. The problem of localization of energy was the reason for the use of the thermocouples; this is a weakness not only in this study but also in any work which depends on accuracy of the direction of the sound field.

This variation in total time of exposure had no consistent effect on the pathological changes noted subsequently.

Follow-up

Lateral roentgenograms were made of both femora of each dog approximately every two weeks for two months after exposure and thereafter once each month until the dog was sacrificed. Additional roentgenograms were made if there was any significant change in the clinical picture, such as a fracture.

In each series of sixteen dogs, two were sacrificed immediately after exposure to ultrasound and two each were killed at intervals of two, four, six, and eight weeks and at four, six, and nine months. All three of the dogs exposed to five watts were sacrificed at twelve months. The femora were subjected to gross examination at death and descriptions were recorded.

Four or five cross sections were made for microscopic study from each femur of one of each pair of dogs exposed to the same amount of energy and followed for the same interval of time. When possible, intact femora were chosen for this part of the study in order to avoid the confusion of changes resulting from fractures in addition to those produced by ultrasound alone.

RESULTS

No attempt will be made to describe the findings in each dog; the data are summarized in Table I.

Figs. 2-A to 2-D: Roentgenographic evidence of delayed healing. The control femur is on the left in each x-ray; the femur on the right in each x-ray had three five-minute exposures to fifteen watts of ultrasound.

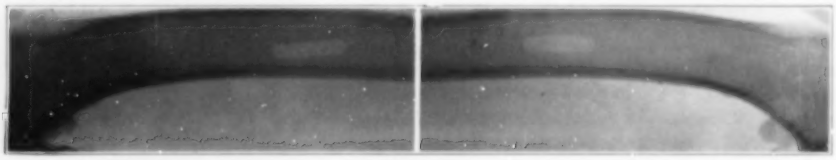

FIG. 2-A

Roentgenograms made before exposure.

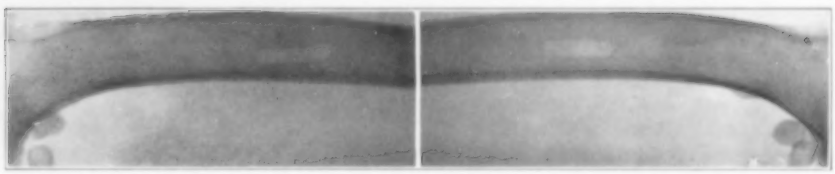

FIG. 2-B

Ten days after exposure some difference between the exposed and the control femora is already apparent.

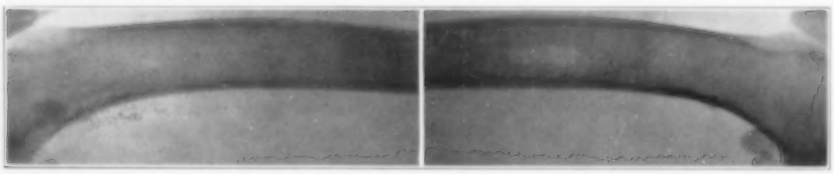

FIG. 2-C

Roentgenograms made three weeks after exposure.

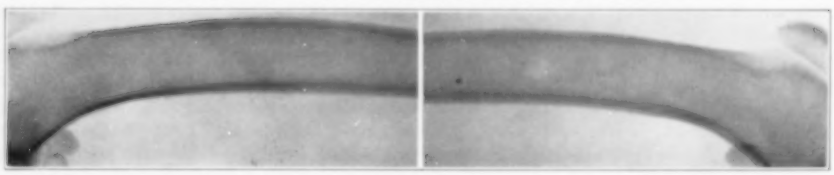

FIG. 2-D

Nine months after exposure, part of the exposed defect may be seen as clearly as in the initial roentgenograms.

No significant complications in the healing of wounds were noted in the entire group.

Variability in response to ultrasound has been referred to frequently in the literature, and this feature was encountered in our study. It was particularly outstanding in a comparison of the increases of temperature noted in the periosteal soft tissues after application of essentially the same amount of energy by the same technique. For example, temperature increases in the dogs exposed to twenty-five watts varied from 6.3 to 31.65 degrees centigrade.

A statistically significant number of fractures occurred after the exposure to ultrasound used in this study. A total of twenty-two of the sixty-seven exposed femora (33 per cent) were fractured, while only three of the control femora (4 per cent) were fractured. The time of fracture of the exposed bones varied from twenty-three to 110 days after administration of ultrasound; ten (almost half) occurred in the fourth week. Fractures were noted in each series except in the three dogs exposed to five watts; five occurred in the ten-watt group, seven in the fifteen-watt group, four in the twenty-watt group and six in the twenty-five watt series.

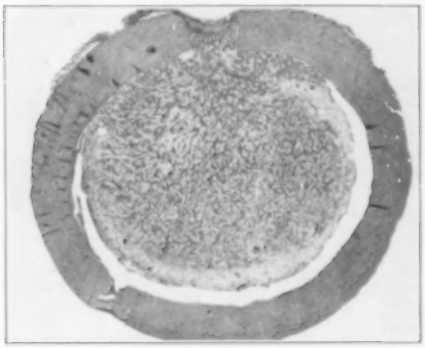

FIG. 3-A

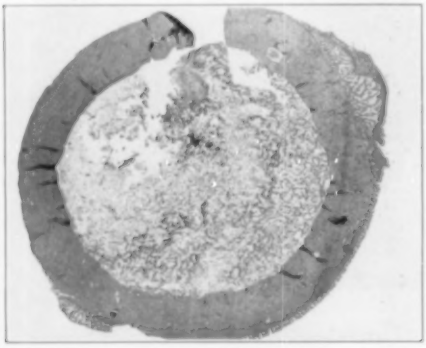

FIG. 3-B

Figs. 3-A and 3-B: Microscopic evidence of differences in healing between the control and the exposed femora at two weeks. (× 3.9, hematoxylin and eosin stain.)

Fig. 3-A: Cross section of control femur, showing defect filled with trabeculae of new bone. Endosteal new-bone formation is pronounced.

Fig. 3-B: Cross section from femur with three five-minute exposures to ten watts of ultrasonic power. In this preparation the defect is empty because its former contents, consisting of dense fibrous tissue, have retracted into the medullary cavity, possibly because of early and insecure attachment to the edges of the defect. Endosteal new-bone formation is considerably less pronounced than in the control.

FIG. 3-C

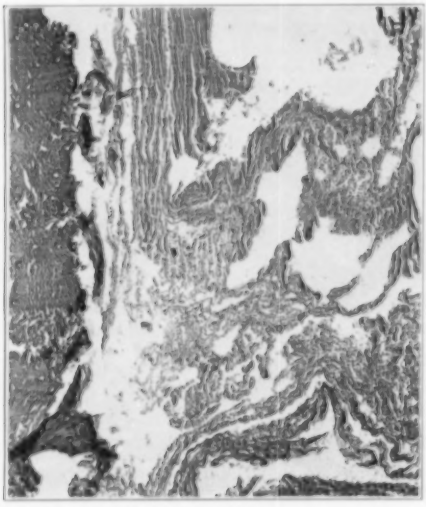

FIG. 3-D

Figs. 3-C and 3-D: Microscopic evidence of differences in healing between the control and the exposed femora at two weeks. (× 88, hematoxylin and eosin stain.)

Fig. 3-C: Control femur, showing trabeculae of new bone in the defect at the right and at one border of the defect at the left.

Fig. 3-D: Exposed femur, showing the fibrous-tissue contents of the defect at the right and the necrotic border of the defect at the left.

A definite delay in the healing of the defects in bone was found in fifty-four of the sixty-four dogs exposed to ten, fifteen, twenty, and twenty-five watts of ultrasonic power (Figs. 2-A to 5). Of the three femora exposed to five watts, one showed early delay in

FIG. 4-A

FIG. 4-B

Figs. 4-A and 4-B: Microscopic evidence of differences in healing at six weeks. (× 4, hematoxylin and eosin stain.)

Fig. 4-A: Cross section of control femur, showing defect filled with mature new bone. Most of the medullary contents have been lost in preparation.

Fig. 4-B: Cross section of a femur with three five-minute exposures to twenty-five watts of ultrasonic power. The defect is filled with dense fibrous tissue, which in this preparation has retracted from the sides of the defect. Medullary fibrosis and endosteal new-bone formation can be seen.

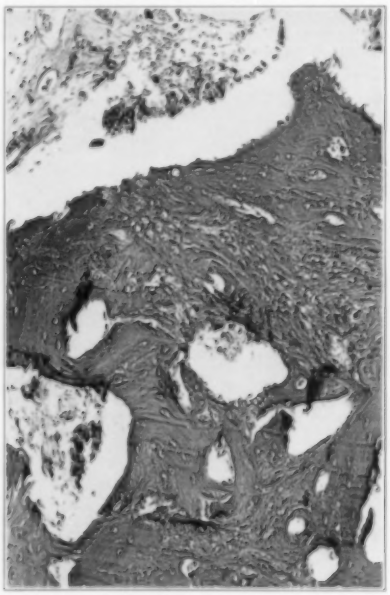

FIG. 4-C

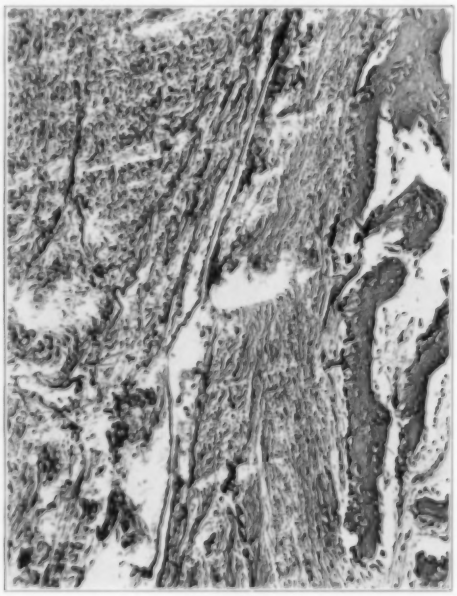

FIG. 4-D

Figs. 4-C and 4-D: Microscopic evidence of differences in healing at six weeks. (× 100, hematoxylin and eosin stain.)

Fig. 4-C: Control femur, showing mature new bone in the defect. The walls of the defect are not shown. The medullary surface is at the top.

Fig. 4-D: Exposed femur, showing the dense fibrous-tissue contents of the defect and a few immature trabeculae of new bone.

healing but subsequently attained a rate of repair equal to that of the other two in this group, as nearly as could be determined. With regard to the twelve femora showing no evidence of delay, either no conclusion could be reached or the rate of repair was equal to that of the control femora. Evidence of accelerated repair was not found in any case.

COMMENT

Table I shows that cortical necrosis is the most dependable sign of damage produced by ultrasound, roentgenographic evidence being a close second. It appears that roentgenographic findings are more valuable in showing delayed healing after surgical trauma

FIG. 5

Microscopic evidence (× 100, hematoxylin and eosin stain) of the state of healing at nine months in a femur with three five-minute exposures to twenty-five watts of ultrasonic power. The border of the defect is below and the dense fibrous tissue filling the defect is above. The low-power view of the exposed bone at nine months was similar to that in Figs. 3-B and 4-B. Several sections through the region of the defect in the control femora failed to disclose any evidence of the surgically produced window in the cortex. The cortex and medullary cavity appeared normal in all the sections.

combined with ultrasound treatment than they are in showing destruction by ultrasound of normal, uninjured bone.

The great variations in the increase of temperatures noted in various dogs of the same group receiving the same dose of ultrasound were probably caused partly by inaccuracy in aiming the field of sound despite our intensive efforts and despite the use of thermocouples as guides. An additional factor was the difference in the depth of tissue of individual fascial and muscle layers among various dogs. No dependably accurate method of placing a given amount of ultrasonic energy at a specific site has evolved from this project. Needle thermocouples have aided in this effort, but their clinical use would be undesirable and not without potential complications. Results of our study have led us to look with skepticism on those reports claiming accurate placement of the field of sound at a specific ganglion located deeply beneath the surface of the skin.

A pronounced difference was noted in the increases of temperature associated with fractures. Fractures occurred after application of the highest temperatures produced but some were associated with much smaller increases. Several femora were not fractured, in spite of the fact that the temperatures applied to them were greater than those of some of the fractured bones. We are unable to explain this discrepancy. The variability just

TABLE I

EFFECT OF ULTRASOUND ON HEALING OF SURGICALLY CREATED FEMORAL DEFECTS IN SIXTY-SEVEN DOGS *

Effect on Exposed Femora	Amount of Ultrasonic Energy (*In Watts*)				
	Five	Ten	Fifteen	Twenty	Twenty-five
Cortical necrosis	0 of 1	4 of 8	7 of 8	8 of 8	6 of 8
Medullary fibrosis	0 of 1	3 of 8	5 of 8	5 of 8	6 of 8
Fibrous tissue in defect	0 of 1	4 of 7†	6 of 7	4 of 6	7 of 8
Normal	0 of 1	2 of 8	1 of 8	1 of 8	1 of 8
Delayed healing	0 of 1	6 of 7	6 of 7	6 of 7	5 of 7
(Roentgenographic evidence)	(1 of 3)	(12 of 14)†	(13 of 14)	(13 of 14)	(12 of 14)
Delayed healing	0 of 1	1 of 8	3 of 8	3 of 8	2 of 8
(Gross evidence)	(0 of 3)	(1 of 16)	(4 of 16)	(4 of 16)	(3 of 16)
Delayed healing	0 of 1	6 of 8	7 of 8	8 of 8	8 of 8
(Microscopic evidence)					
Discoloration,	0 of 1	2 of 8	4 of 8	5 of 8	3 of 8
eburnation, or both	(1 of 3)	(5 of 16)	(6 of 16)	(7 of 16)	(6 of 16)
Fractures	(0 of 3)	(E. 5‡)	(E. 7)	(E. 4)	(E. 6)
		(C. 1‡)	(C. 0)	(C. 1)	(C. 1)
No conclusion	0	1 of 8	1 of 8	1 of 8	1 of 8
		(2 of 16)	(2 of 16)	(1 of 16)	(1 of 16)
Equal repair	(2 of 3)	(2 of 16)	0	0	0
Total with delayed healing	(1 of 3)	(12 of 16)	(14 of 16)	(15 of 16)	(15 of 16)

* The figures without parentheses indicate the incidence of a given characteristic in the group of dogs studied microscopically. Numbers in parentheses indicate the incidence in the total number of dogs in each group. The latter was determined whenever possible.

† Complete data could not be obtained in all cases, either because of an apparent loss of the defect in the slides studied or because post-irradiation x-rays were not available for those dogs sacrificed immediately after exposure.

‡ E, exposed femora; C, control femora.

referred to does, of course, play a part in it, but the values found in individual cases were too constant, as a rule, to place the entire responsibility on this.

The rate of healing of fractures which occurred subsequent to ultrasonic exposure did not appear to vary from that of the controls and of other dogs we have observed. This aspect of the problem had not been anticipated and, therefore, specific data concerning this observation were not recorded. Our conclusion is based primarily on impressions rather than on statistics. It was noted in several cases that definite evidence of delay in healing of the defects was concomitant with relatively normal healing of associated fractures. Also, both endosteal and periosteal new-bone formation with normal-appearing cells was seen simultaneously with cortical necrosis in adjacent regions.

As reported in our previous paper [1] medullary fibrosis associated with cortical necrosis was the most frequent finding. This is comparable to the changes reported by Rouiller and Majno, which were produced solely by heat. In essence, they found microscopic signs of necrosis of bone appearing first in the central or medullary portion of the cortex; the necrosis later spread peripherally toward the periosteal surface. They concluded that the entire thickness of the cortex was made devoid of cellular life by the heat. The early signs of this necrosis consisted in pyknosis of the osteocytes; later there was disappearance of these cells and vascular erosion of the Haversian systems. Signs of necrosis appeared first near the medullary cavity, because of the relatively good blood supply in that area, and proceeded peripherally. We found no explanation for the medullary fibrosis associated with cortical necrosis unless it represented an abortive effort at osseous repair. Small zones of osseous hyperplasia were seen occasionally arising from this dense fibrous tissue; however, during the follow-up period this activity was never seen to replace the

fibrous tissue and it did not appear to contribute in any way to the repair of the defect.

One general impression gained from the microscopic studies was that the exposed femora often exhibited a greater amount of new-bone formation, either endosteal or as the result of fibrous metaplasia, than did the controls. This new bone in the exposed femora was not at the defects but at various distances from them, whereas new bone in the controls was in and adjacent to the defects. In the exposed bones, there was a minimal amount of new bone or none in the defect exposed to ultrasound as compared with the pronounced formation of new bone in the control defect. It was our opinion that, although a type of osteogenesis apparently was stimulated to a greater extent by creation of the defect combined with ultrasound than it was by the defect alone, the osteogenesis resulting in the former case was purposeless and without direction as far as repair of the defect was concerned. This purposeless hyperplasia or metaplasia suggests a possible tendency toward the realm of malignant disease that deserves investigation.

The potentially destructive force of ultrasonic energy again has been pointed up by the results of this study. The occurrence of necrosis of bone in the absence of demonstrable roentgenographic changes demonstrates the danger of using the latter criteria as an indication that damage has not been produced. Even slight cortical necrosis makes a bone more susceptible to fracture; since this change has been demonstrated as long as nine months after exposure to ultrasound, this possibility should be remembered when manipulation of a joint is considered after ultrasonic therapy. Caution is particularly warranted when the surgeon performing the manipulation does not know the complete circumstances of the previous therapy, such as dosage, occurrence of pain during exposure, and the number and frequency of exposures. The threshold dose for the production of damage to bone as determined by microscopic evidence is still unknown. In view of the comments already made on the variability of results, as well as the findings of cortical necrosis after a stroking application of as little as ten watts of total ultrasonic power from a radiating area of ten square centimeters for three five-minute periods, it appears that a narrow margin of safety probably exists.

It must be acknowledged that the technique of ultrasonic treatment used in this study cannot be applied in therapy of human patients. Since the animals were anaesthetized, the safety factor of periosteal pain has been eliminated, so that the amount of energy striking the bone in these dogs was undoubtedly greater than that received by patients. In addition, the energy was applied in three closely timed periods instead of twice a day, or daily, for a greater number of exposures than would be used clinically.

For these reasons, the significance of the preceding conclusions for clinical application is unknown at present. It may well be that the use of periosteal pain as an indication of excessive dosage will avoid all of the effects observed in this study, but the question arises as to whether a physiological or a psychological dose is being used. As yet, adequately controlled studies on human subjects are insufficient for scientific evaluation, and the potential changes described above should be kept in mind.

SUMMARY AND CONCLUSIONS

A study was made of the effect of ultrasonic energy on the healing of defects created surgically in the femora of sixty-seven dogs. The ultrasonic energy was applied to anaesthetized dogs with a power ranging from five to twenty-five watts in various groups of animals.

Stimulation of the healing of these defects in bone was not seen. Instead, a delay in healing associated with medullary fibrosis and necrosis of bone was noted. This agrees in part at least with work reported by others. In view of recently reported studies claiming stimulation of the healing of fractures following use of a different technique of ultrasonic application and smaller doses, the need for further investigation along these lines is obvious.

It is probable that more frequent and less concentrated exposures, with use of a technique and dosage comparable to those used clinically, applied to non-anaesthetized animals would provide the answer to this question. Now that the effects of more intensive amounts of energy have been studied, this would appear to be the next step.

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DISCUSSION

Fracture of the Distal Radial Shaft

(*Continued from page 264*)

of the radius while the ulna is intact will produce slipping and angulation. Therefore, it becomes obvious that in the treatment of most of these fractures there must be accurate reduction, rigid internal fixation, and supplemental bone or an osteogenetic stimulus.

Screws and nails are inadequate for fixation of these fractures; a straight intramedullary nail is contraindicated in a curved bone, and there is no nail available which will adequately fill the medullary canal of the radius. Therefore we cannot expect adequate immobilization with these "props". Plates and screws, if properly applied, will secure the fracture; however, I believe that Phemister, or small barrel-stave, grafts should be applied to the dorsal, volar, and radial sides of the fracture at the time of the initial operation. After this procedure and while the patient is still under anaesthesia, the stability of the radio-ulnar articulation should be ascertained. I cannot agree with Dr. Hughston that in fresh fractures the initial plan of treatment should include resection of the distal end of the ulna. Certainly this is true in fractures treated late, but for a fresh fracture that is well immobilized internally it is unnecessary.

I believe that the best form of treatment of the forearm is to secure plate and screw fixation with bone grafting. The ulna, a straight bone, can be fixed by means of a large intramedullary pin, but healing of this fracture will be augmented by small, multiple, barrel-stave bone grafts.

I would like to hear Dr. Hughston's opinion in detail as to what operative procedure and follow-up care is best suited for the treatment of this fracture.

Dr. Hughston (closing): Dr. Stewart asked for our opinion as to the best treatment for this fracture. From experience, we believe that initial open reduction and rigid internal fixation is the treatment of choice. A four-hole plate provides the desired rigidity of fixation. If this fracture is seen late, open reduction and bone-grafting of the fracture with intramedullary fixation and excision of the distal portion of the ulna assure the best results. Screws do not hold in the osteoporotic bone seen in fractures treated late. Intramedullary pins produce the desired immobilization in fractures treated late when the distal ulna is excised. Absorption at the fracture site cannot produce recurrence of the subluxation when the distal portion of the ulna is excised. In fractures treated late by open reduction, the callus-filled medullary canal gives adequate stability to the intramedullary pin.

We do not believe that the distal portion of the ulna should be routinely excised in the initial treatment of fresh fractures, but we feel that it would be well to consider the use of such a procedure if instability is demonstrated.

Dr. Patterson commented that our number of failures, using conservative treatment, is high. We agree that it is too high to justify closed reduction as a routine form of initial treatment for this fracture. I think that the number of poor results reported frankly and demonstrated by roentgenogram indicates the unbiased honesty of the presentation. During the three years we have been working on this study, increasingly aware of the complexity of this fracture, we have treated several of these fractures satisfactorily by open reduction and internal fixation. These have not been included in this presentation.

Patellectomy and Fascial Grafting in Certain Cases of Long Standing Disruption of the Quadriceps Mechanism

A Case Report and Review of the Literature

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The late surgical repair of a disrupted quadriceps extensor mechanism secondary to unsuccessful treatment of a fracture of the patella is the subject of the following case report.

S. M., an Army Sergeant, forty-five years old, was initially seen in October 1953, because of pain in the right knee. Inability to extend the knee and instability of the knee were secondary complaints. Two and a half years previously, the patient had sustained a fracture of the right patella in an automobile accident. At another hospital, the distal pole of the patella was removed and the patellar tendon was fixed to the proximal pole. The details of technique and the method of suture were not known. A cylinder cast had been applied. When this cast was removed six weeks after surgery, there was 90 degrees of passive motion at the knee, but active extension was completely lacking. The patient learned to walk with a swing-through gait and locked his knee in hyperextension for stability. He accepted his disability and for two and a half years was quite active. Increasing pain, however, led him to seek medical advice.

FIG. 1

Right knee, preoperative (medial view), showing prominence of femoral condyles and high riding patella. There was no active extension.

Examination of the right knee revealed no active extension. The remaining proximal pole of the patella was displaced upward by the pull of the quadriceps. Its distal margin was four inches above the joint line when the knee was in complete extension. The prominent femoral condyles (Fig. 1) were tender to direct percussion. Attempted extension of the knee resulted in motion of the patellar fragment proximally about one inch. There was a full range of passive motion, and 5 degrees of hyperextension. No collateral or cruciate ligament laxity was present. Roentgenograms revealed the patellar fragment to consist of approximately one-half of the patella, with rather marked osteophytic irregularities. No other abnormalities of the joint were seen in the roentgenograms.

It was felt that reconstruction of the quadriceps mechanism was indicated and that the proximal pole of the patella should be excised because of its irregularity and the probability of patellofemoral arthritis. A Kirschner wire was passed through the patella. Four pounds of traction applied for a week resulted in three-fourths of an inch of lengthening of the quadriceps muscle. On October 21, 1953, the knee joint was approached through a long median parapatellar incision. A tourniquet was not used because it would have restricted quadriceps mobility. Reflection of the skin and subcutaneous tissues over the anterior aspect of the knee revealed a thin fibrous sheet lying over the area of the joint. This weak tissue bridged the defect in the extensor mechanism. The under surface of this sheet was shiny, smooth, and appeared to have a synovial lining. The remaining portion of the patella (proximal pole) was removed *en toto*. There was insufficient soft tissue to allow closure of the resulting defect by direct apposition of the edges. Five strips of fascia lata, each approximately six inches by three-fourths of an inch in size, were obtained from the opposite thigh. Four of these strips were sutured into slits in the end of the quadriceps tendon. From the fibrous sheet overlying the anterior aspect of the knee joint a flap was created with its base proximal. The four strips of fascia lata, together with this flap, were pulled distally and were anchored to the periosteum of the tibia just below the margin of the articular cartilage. The strips of fascia were passed through four tunnels in the patellar ligament (Fig. 2). Under considerable tension, the grafts were sutured in place with heavy

chromic catgut. The fifth piece of fascia was sutured re-enforcing the others, closure was accomplished, and the limb was placed in a cylinder cast in full extension.

When the cast was removed six weeks later, the range of knee motion was 160 degrees to 180 degrees. Three weeks later, during which time the patient received daily whirlpool therapy and active guided exercises, as well as progressive-resistance exercises, the patient was able to lift the exercise boot with five pounds through a range of motion from 85 degrees to 175 degrees. A month later, because he had lost some extension (the maximum being 160 degrees) his extremity was replaced in a cylinder cast in extension for one week. This resulted in substantial improvement. Three months following surgery he was walking well without a limp, had no pain or tiredness in the knee on walks up to one mile, was lifting twenty pounds with the boot, and had a range of motion of 60 degrees to 170 degrees. Eight months after surgery the range of motion

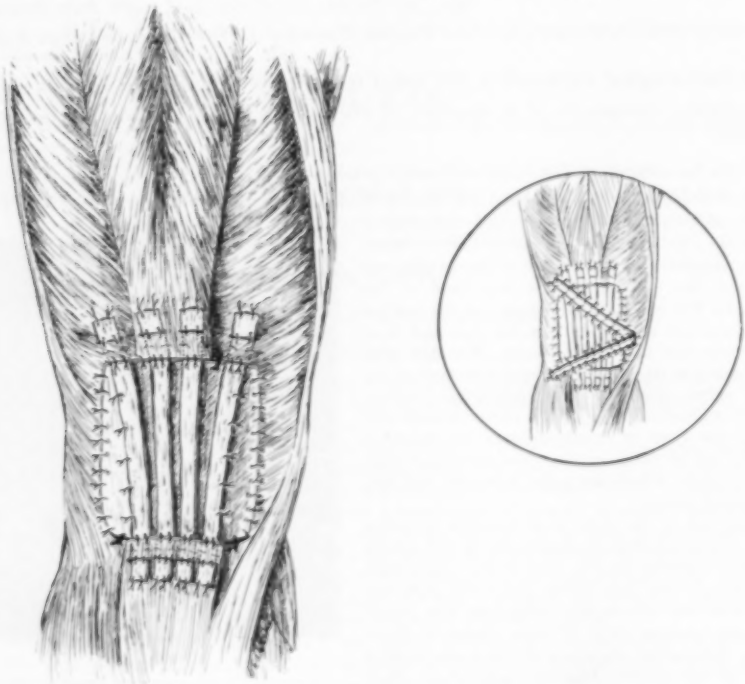

FIG. 2

Four strips of fascia lata were carried through the hole left after removal of the proximal portion of the patella and were brought out of the suprapatellar pouch through slits in the quadriceps tendon and sutured. The hole was then closed around these fascial strips. At that point the strips of fascia, and the flap created from the thin fibrous tissue which bridged the gap in the quadriceps mechanism, were sutured to the periosteum of the proximal portion of the tibia just distal to the articular cartilage. The fascial strips were then passed through slits in the patellar ligament. The insert shows how a fifth strip of fascia lata was over-sewn reinforcing the others.

was the same and he could lift thirty pounds throughout this range (Figs. 3-A and 3-B). The patient was last seen twenty months after surgery, at which time he reported that his knee had continued to improve. He was able to walk several miles, could walk upstairs in a normal fashion, and had no pain.

DISCUSSION

The loss of quadriceps extensor power constitutes a serious disability. The resulting weakness leads to instability of the knee, a limping gait, the inability to climb stairs in the normal fashion, genu recurvatum, and even pain. Such loss of quadriceps power may be from neurogenic, myopathic, or traumatic causes. Of the traumatic causes, aside from extensive damage to the quadriceps muscle bellies themselves, there may be disruption

in the continuity of the quadriceps tendon, the patella, or the patellar tendon. In patients in whom the condition is of long-standing, and in patients in whom a similar situation results from non-union of fracture of the patella, there is a transverse elliptical defect in the extensor mechanism at the level of the discontinuity. After some time, the synovial lining extends across the defect and in this region lies subcutaneously. The rough fracture edges or abortive attempts at osseous repair can lead to irregular bony surfaces. There may

FIG. 3-A

Right knee, six months after surgery, showing active extension to 170 degrees.

FIG. 3-B

Right knee, six months after surgery, showing maximum flexion to 90 degrees.

be abrasion of the patellar groove. There may be joint effusion. Quadriceps atrophy develops [18].

Suggested methods of restoring the continuity of the quadriceps mechanism after long-standing disability are many. Direct repair of the patellar fracture, if possible, was advocated by Phemister. This is perhaps best done by using fascia lata [9]. If a gap persists between fragments despite release of restricting bands, several alternatives remain. Phemister approximated the fragments with a heavy silk suture and bridged the gap by a sheet of fascia. In a similar maneuver, Gallie spanned the defect with fascia lata [8] but

subsequently recommended using Achilles tendon [9]. Plastic soft-tissue procedures have been recommended [4]. Brickner cut the quadriceps tendon with its attached patellar fragment completely free and shifted it distally. These measures gain continuity at the expense of losing power.

Since early descriptions by Scudder (1898) and Rogers (1908), and its advocacy by Brooke, patellectomy has become increasingly common in the treatment of certain patellar fractures. It would seem especially advisable in cases of non-union with rough articulating surfaces and the possibility of traumatic arthritis. Paschall, Ghormley, and Dockerty recommended partial or total patellectomy for all cases of non-union of patellar fractures.

Closure of the defect following total patellectomy is a problem of varying difficulty. Simple plication is frequently possible [10, 15]. The defect has been left open [13] and soft-tissue flaps have been developed [12, 16]. Fascia lata, however, seems almost ideally suited for use in difficult closures.

The use of fascia lata as free grafting material to re-enforce or replace a dense connective-tissue defect or weakness is a well accepted procedure. Experimental work has shown that free autogenous fascia lata grafts in human patients remain viable and maintain their gross and histological characteristics. They are not replaced by host fibroblasts [7, 8, 14]. Although preserved heterogenous fascial grafts may be used successfully (in which case there is replacement by host fibroblastic cells [14]), the ease with which abundant autogenous fresh fascia lata can be obtained makes this unnecessary.

Intermittent stress on the graft promotes hypertrophy [3, 5, 11]. There is no significant stretching or contracture [7, 8]. Herniation of vastus lateralis through the donor site, if it occurs at all, disappears spontaneously in six to twelve months [6, 8, 14]. Gallie and LeMesurier have shown that removal of surrounding areolar tissue is necessary for satisfactory union between fascia lata and other fibrous tissues. The reader is referred to their papers for a detailed discussion of the handling of fascia lata [7, 8].

Thus, the present case illustrates the main points involved in this problem and serves as an excellent example in showing:

(1) Total patellectomy is a recommended procedure for long-standing patellar fractures if traumatic patellofemoral arthritis is present or probable.

(2) Free autogenous fascia lata grafts will successfully bridge large defects and will withstand increasing strain.

(3) It is sometimes possible to restore quadriceps muscle function after a long period.

NOTE: The authors wish to acknowledge the counsel and assistance of Major R. R. Kessler and Captain D. A. Bindbeutel.

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DISCUSSION

Slipped Femoral Epiphysis

(Continued from page 303)

described. The boy complained of pain, he had limited hip motion, and a limp. Would Dr. Heyman consider removal of the projecting portion of the neck to improve the limited hip motion in this patient? At that time, we nailed the hip *in situ*. Sixty-one months later, when the patient was eighteen years old, he had no limp, no pain, and demonstrated an index of motion of 86.91 and a total percentage of normal hip function of 95.63. The roentgenogram of that date indicated that the projecting portion of the neck had become smooth.

I wish to make a plea for the general use of an accepted standard for comparison, especially when measuring the motion or function of hip joints or any joints under discussion. We use the index of motion described twenty-five years ago by Ferguson and Howorth [a] which gives a numerical evaluation to motion. To say that a result is excellent, good, or satisfactory does not define shades of difference sufficiently accurately for comparison. Comparison is possible when descriptive terms can be reduced to numbers.

At the joint Meeting in 1948, we showed roentgenograms (Fig. 11 in a former publication [b]) of another thirteen-year-old boy who had marked slipped capital femoral epiphysis. He had complained of pain and limp five months previously when he came to the clinic; roentgenograms were made at that time but were not seen. During the five months' interval further slipping occurred. I wonder if Dr. Heyman would recommend removal of the projecting portion of the neck and use of the bone to fuse the epiphysis in this patient.

We did an open reduction and nailing. Thirteen months later the patient's index of motion was 78.99, there was no limp, no pain, and the total percentage of normal hip fusion was 92.90.

We do not advocate fusing a growing upper femoral epiphysis since it may contribute to the total length of the femur. Nailing does not necessarily stop this growth, as has been observed in four of our patients. The roentgenograms of one of these (Fig. 19 in a former publication [b]) was shown at the Quebec Meeting.

I do not wish to imply that these nails are innocuous indefinitely. We have seen four instances in which the femoral shafts have been fractured by football injuries. Therefore, after the epiphysis has grown away from the nail or has fused, we advocate prompt removal of the nail and abstenance from contact sports for at least one year.

[a] Ferguson, A. B., and Howorth, M. B.: Slipping of the Upper Femoral Epiphysis. A Study of Seventy Cases. J. Am. Med. Assn., **97**: 1867–1872, 1931.

[b] Klein, Armin; Joplin, R. J.; Reidy, J. A.; and Hanelin, Joseph: Roentgenographic Changes in Nailed Slipped Capital Femoral Epiphysis. J. Bone and Joint Surg., **31-A**: 1–22, Jan. 1949.

Dr. Heyman (closing): In closing the discussion I want to answer Dr. Joplin's questions. During his discussion he showed a slide of a roentgenogram of a slipped femoral epiphysis with a wide epiphyseal line and moderate displacement. Subsequently, he said, the epiphysis became severely displaced. He asked whether I would have done an epiphyseodesis in this patient. Yes, I would have done so, because this would have prevented the severe displacement. In the second case, Dr. Joplin said that the patient had an excellent range of motion and good function without disability, but the roentgenogram showed a prominence of bone at the neck of the femur similar to that which has been described. Dr. Joplin asked whether I would

(Continued on page 413)

Eosinophilic Granuloma of the Femoral Shaft Simulating Ewing's Sarcoma

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Although an increasing volume of literature on the subject records that eosinophilic granuloma of bone can simulate Ewing's sarcoma clinically and roentgenographically, we have not always found this fact to be well appreciated. It was felt, therefore, that a short review of eosinophilic granuloma and a presentation of two illustrative cases would be of value.

The evolution of the present concept and treatment of eosinophilic granuloma may be traced by referring to the articles of Fraser, Lichtenstein and Jaffe, Otani and Ehrlich, Farber, and Green and Farber. Miscast as a "myeloma" and a "granulation tumor", and later considered to be an expression of disordered lipoid metabolism, eosinophilic granuloma is now popularly classified as a localized non-lipoid histiocytosis related to the chronic disseminated Schüller-Christian disease and acute or sub-acute disseminated Letterer-Siwe disease[4, 5].

Eosinophilic granuloma is a well localized, usually single, histologically distinct granuloma of unknown etiology which has its origin in the medullary cavity of a bone and tends to expand, erode, and perforate the cortex. The microscopic features, well described by Lichtenstein and Jaffe[4, 6], are said to allow easy differentiation of the non-lipoid histiocytoses from other conditions.

FIG. 1-A

Although eosinophilic granuloma must be differentiated from a number of infectious, metabolic, developmental, and neoplastic bone lesions, its clinical and roentgenographic similarity to Ewing's sarcoma of long bones is of immediate concern to this report. Ewing's tumor and eosinophilic granuloma have a similar age of occurrence (under twenty) and may produce the same symptoms (pain, tenderness, loss of function, and swelling). Such symptoms of Ewing's tumor are usually of some months' duration, while in the case of eosinophilic granuloma the symptoms usually endure for days or a few weeks. The roentgenograms of both show rarefying lesions arising in the diaphyseal medullary cavity expanding and eroding the cortex. With perforation of the cortex, both lesions cause deposition

FIG. 1-B

Figs. 1-A and 1-B: Case 1. Preoperative roentgenograms of left femur, showing eosinophilic granuloma of femoral shaft. Note the erosion of the medulla and cortex and reactive periosteal new bone, which has a laminated appearance.

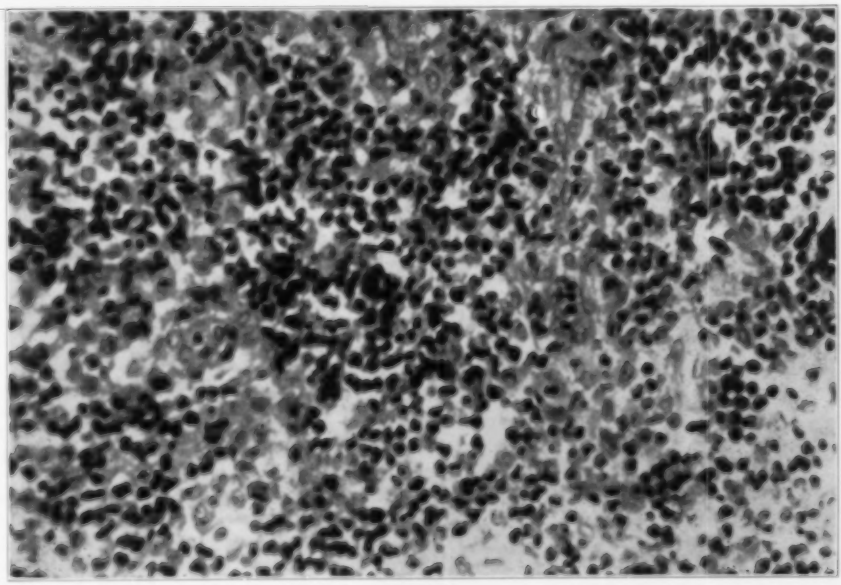

FIG. 1-C

Photomicrograph (× 200) showing many polymorphonuclear leukocytes and occasional giant cells throughout the granuloma. Note the histiocytic background of the lesion. Most of the leukocytes are eosinophils.

of reactive new bone. Not infrequently periosteal elevation occurs and lamination by periosteal new bone appears—the so-called "onionskin" effect. Eosinophilic granuloma may be more sharply defined than Ewing's tumor but is often indistinguishable from it. Only microscopic examination of biopsy material will reveal the true nature of any suspect lesion.

The following cases were recently seen on the orthopaedic service of the Royal Alexandra Hospital.

FIG. 1-D

FIG. 2-A

Fig. 1-D: Roentgenogram of left femur three months after curettement and radiation, showing sclerosis of the lesion. Cortical thickening remains.

Fig. 2-A: Case 2. Preoperative roentgenogram showing marked erosion of cortex with perforation and extensive periosteal new-bone formation. The lesion is extremely active, suggesting malignant growth. The location and mode of growth would be more readily expected in Ewing's sarcoma than in eosinophilic granuloma.

CASE REPORTS

CASE 1. G. W., a three-year-old girl, was admitted to the Royal Alexandra Hospital on November 30, 1953, with a three-month history of intermittent fever and intermittent pain in the left knee. For the last two months she had been showing an increasing limp favoring the left lower extremity. Her illness allegedly began with "flu" and pain in the lower extremity which, in view of a concomitant epidemic, had originally been considered poliomyelitis. Since August the patient was said to have appeared pale and to have tired easily.

The child had had no significant past illnesses, but two aunts had died of tuberculosis and the mother had worked in a tuberculosis sanatorium.

Physical examination revealed a moderately well nourished, afebrile, slightly pale little girl who preferred to hold her left hip and knee in slight flexion. The throat was slightly injected and the cervical lymph nodes were enlarged bilaterally. The chest and cardiovascular system were clinically normal. No tenderness or enlargement of organs was detected on examination of the abdomen. The upper portion of the left thigh was slightly tender; it measured eleven and three-quarter inches in circumference, one-half inch less than the right. The white-blood-cell count was 8,700, with 46 per cent neutrophils, 48 per cent lymphocytes, 1 per cent monocytes, 4 per cent eosinophils, and 1 per cent basophils. The sedimentation rate (Wintrobe) was twenty-three millimeters in one hour. Urinalyses were negative. Roentgenograms of the left femur showed an area of radiolucency in the upper third with some periosteal new-bone reaction (Figs. 1-A and 1-B). Roentgenograms of the right femur, both arms, the skull, and the chest were normal. The Mantoux test and the Gruber-Widal reaction were negative. A provisional diagnosis of Ewing's sarcoma was made.

The patient was seen in consultation at a diagnostic clinic. After review of the findings, the consultants felt that the clinical and roentgenographic evidence pointed so definitely to a diagnosis of Ewing's tumor that immediate deep roentgen therapy was advisable. Surgery, it was argued, could lead only to dissemination

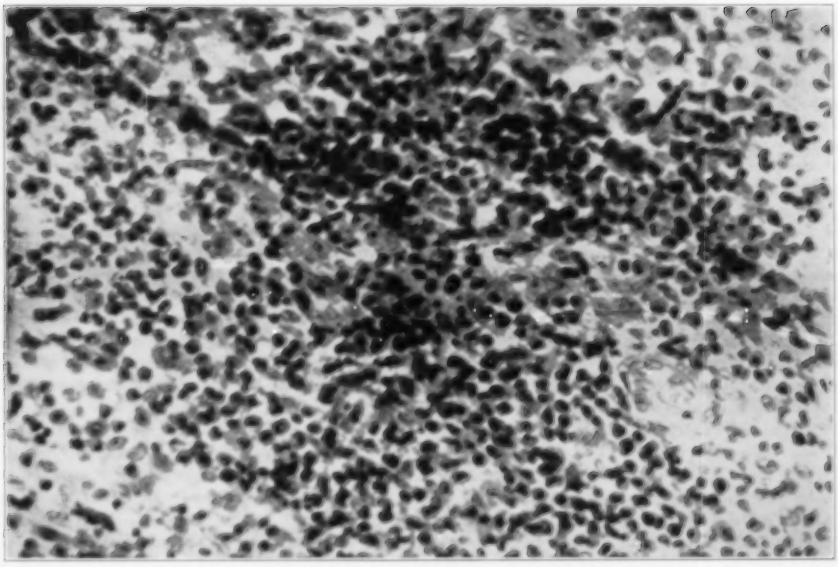

FIG. 2-B

Photomicrograph (× 200) of tissue from Case 2 which shows a histiocytic granuloma characterized by the presence of many eosinophilic leukocytes: eosinophilic granuloma.

FIG. 2-C

Fig. 2-C: Follow-up roentgenogram six and one-half months after curettement of eosinophilic granuloma. Aside from residual cortical thickening, the femur shows no evidence of recurrence of the lesion.

of the tumor. In spite of his concurrence with the consultants' diagnosis, the attending surgeon (F.G.D.) did not share their views on surgery and refused to allow treatment without biopsy. Accordingly, an exploratory operation was carried out.

At operation the soft tissues overlying the lesion were found to be in fairly normal condition. There was noticeable periosteal thickening. The tumor cavity was entered through thickened cortical bone and was found to be filled with blood and soft, friable, whitish material. The cavity was curetted as well as possible and the contents were sent for pathological examination. The microscopic picture was that of typical eosinophilic granuloma (Fig. 1-C).

The child was discharged from hospital on December 19, 1953, following deep roentgen therapy (a total of 800 r). Roentgenograms made at the time of discharge showed that the left femur was beginning to recalcify. Follow-up examination and roentgenograms on March 18, 1954, showed complete return of painless function of the limb, with calcification and reossification of the

bony defect (Fig. 1-D). No recurrence of the femoral lesion was evident fifteen months after biopsy and no new lesions had appeared.

CASE 2. P. S., a boy two and one-half years old, allegedly injured his left lower extremity when he fell down a flight of stairs on August 7, 1954. Subsequently he was noted to have a slight limp favoring the left lower extremity. His appetite became poor and there was some weight loss. As the limp gradually increased, the patient complained of more and more pain in the extremity. Accordingly the child was admitted to the Hospital on August 21, 1954, for investigation.

Examination revealed a well nourished, tanned, slightly feverish child with enlargement of the tonsils and injection of Waldeyer's ring. The tonsillar nodes were bilaterally enlarged and the left anterior cervical nodes were palpable but non-tender. The pulse rate was 154 per minute and a soft systolic murmur was heard at the apex of the heart and along the left sternal border. Chest examination was otherwise negative. The abdomen was non-tender and no organs or masses were palpable. There was slight swelling of the mid-portion of the left thigh, which measured one-half inch more in diameter than did the right thigh at that point. There was moderate tenderness over the area of the swelling, but no redness of the overlying skin. The temperature at admission was 102 degrees. The white blood count was 7,000 with 66 per cent neutrophils, 29 per cent lymphocytes, 4 per cent monocytes, and 1 per cent eosinophils. The sedimentation rate (Wintrobe) was fifteen millimeters in one hour. Roentgenograms of the left hip showed an area of radio translucency in the mid-shaft of the left femur involving both the medulla and the cortex. The involved area was surrounded by extensive periosteal new-bone formation (Fig. 2-A). X-rays of the skull, chest, and right femur showed normal findings. The Mantoux test was negative.

A provisional diagnosis of Ewing's sarcoma was made, osteomyelitis being considered a second possibility. In spite of previous experience, the presence of eosinophilic granuloma was not seriously suspected.

At exploratory osteotomy the periosteum was found to be five or six times the normal thickness. The periosteum and the overlying tissue were slightly oedematous and congested. The underlying cortex was somewhat spongy. The periosteum was easily stripped back and a cortical window was cut with ease. Soft, brown, friable tissue was curetted from the medullary cavity and was sent for examination. Microscopic study revealed the lesion to be eosinophilic granuloma (Fig. 2-B).

Nine days after biopsy and curettement the child was discharged to his home in a unilateral hip spica. Follow-up examination on March 8, 1955, revealed no residual symptoms of the lesion. Roentgenograms made at that time showed recalcification of the involved area (Fig. 2-C).

DISCUSSION

The concept of biopsy of bone lesions before definitive treatment is undertaken has unfortunately not received universal acceptance. It is generally recognized that the pathologist's diagnosis may depend to a large degree on the x-ray examination and the clinical history of the case involved even when abundant biopsy material is supplied; yet many practitioners still expect to arrive at a definitive diagnosis by the presence of roentgen shadows alone. It should again be emphasized that single or multiple roentgenograms, alone or in combination with the clinical history, are not reliable indicators of benign or malignant growth. The serious effects of under-diagnosis of a malignant bone lesion are obvious. The serious effects of over-diagnosis of benign lesions should be equally obvious if one considers the crippling effects of unnecessarily irradiated epiphyses or ablated limbs, or the useless expense and anxiety imposed upon patients and their families. The authors' two cases are presented mainly to underline the fact that eosinophilic granuloma may simulate Ewing's tumor roentgenographically. We hope they will also serve to strengthen the growing belief that biopsy prior to treatment of bone lesions is mandatory even when roentgenograms are "diagnostic".

SUMMARY

The fallacy of complete reliance on roentgenographic evidence for the diagnosis of bone lesions was recently brought to our attention by two cases of eosinophilic granuloma of bone which, on the basis of roentgenographic examination, were believed to be "typical" Ewing's tumors.

NOTE: The authors are indebted to Dr. P. W. Davey and Dr. G. M. Martin of the Department of Pathology, and Dr. C. F. Hyndman, Chief Radiologist, Royal Alexandra Hospital, for their cooperation in the preparation of this paper. We wish to thank Mr. Z. Zielinski for the preparation of the illustrations.

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DISCUSSION

Slipped Femoral Epiphysis

(*Continued from page 407*)

remove this prominence. Of course not. We treat the patient and not the roentgenogram. If, however, this patient had disabling limitation of abduction and of internal rotation, I would remove the prominence.

Here is a problem which I have found no answer to, but it should receive consideration before any radical operation is proposed. There have been a great number of slipped epiphyses in children during past years; many of these must have healed with severe displacement, and yet, during my practice in adult orthopaedic surgery I have seen very few patients who complained of disability caused by an old unreduced slipped epiphysis. I do not know whether this bone prominence will absorb spontaneously in time and no longer be disabling, or whether some kind of a molding process takes place, adapting it and the surface of the acetabulum to one another.

We do not want to do an unnecessary operation. The patient with the severe bilateral displacement described in the paper had disability of one hip for two years and of the other hip for one year. We felt that we had waited long enough and operated. The patient promptly recovered excellent motion and function following the removal of the obstruction to motion.

Dr. Klein, Dr. Joplin, Dr. Reidy, and Dr. Hanelin report excellent results after open reduction and nailing. I am willing to take their word for it. I am speaking only from my own personal experience and from the experience of many others. Our results have been poor following open reduction or cervical osteotomy.

After several encouraging good results following the conservative procedure described in this paper, I was persuaded by younger and more confident men with whom I had recently become associated to try once more open reduction and nailing for severely displaced epiphyses. We did this in the next two patients. The first open reduction and nailing resulted in aseptic necrosis, and as a consequence we had to do an arthrodesis of the hip. The second patient also had such a poor result that we advised arthrodesis. The brother of the first patient came to us later with a similarly slipped epiphysis. Did we perform an open reduction or cervical osteotomy and nailing upon him? We did not. We removed the knob.

Giant-Cell Tumor of the Patella

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The practice of reporting rare lesions has justified itself by making possible their early recognition and treatment. With this in mind, the following discussion and case reports are presented.

The patella is an uncommon site for giant-cell tumors which occur fairly frequently in other bones. The microscopic appearance of these tumors is the same regardless of the bone or portion of bone involved. Most pathologists agree that it is difficult to distinguish between benign and malignant giant-cell tumors in the early stages[3, 5, 8]. When the lesion appears in a dispensable bone such as the patella, the prognosis is improved. It goes without saying that these tumors should be treated by patellectomy. The operation does not entail any difficulty or cause prolonged postoperative disability.

CASE 1. N. A. H., a white woman, twenty years old, was admitted to the Chicago Wesley Memorial Hospital on January 9, 1955, with a chief complaint of pain and swelling in the left knee of three months' duration. The patient gave a history of having sustained a fall in October 1954. The left knee was twisted at that time but the patella did not receive any direct impact. Considerable pain was experienced in the knee following the injury, necessitating her absence from work for a period of several days. Because of persistent pain and weakness in the knee, the patient fell several times, reinjuring the knee. A few weeks before admission the knee became increasingly swollen and tender.

Examination revealed a thin, pale, delicate female. The left knee was swollen, red, hot, and tender. The quadriceps muscle was visibly atrophied. Attempted motion of the knee caused evident quadriceps spasm. Extension was limited to 160 degrees and flexion to 120 degrees.

FIG. 1-A

Pneumo-arthrogram showing encroachment of the knee joint cavity by soft-tissue mass. The patella is expanded and completely involved with the tumor.

Roentgenograms made on admission showed the patella to be expanded and completely involved with tumor. Pneumo-arthrography showed encroachment of the joint cavity by a soft-tissue mass of the same density as muscle (Fig. 1-A). Although no fracture of the patella was seen in the roentgenograms, we surmised that there had been seeding from the patella to the joint lining, probably as the result of a fracture.

The patient was taken to surgery on January 13, 1955. The joint was exposed through a median parapatellar incision, and the patella was dislocated laterally. The entire synovial membrane and fat pad were involved with tumorous growth (Fig. 1-B). The patella was friable and showed evidence of an old fracture through the articular surface. Patellectomy, radical synovectomy, and bilateral meniscectomy were done at this time. Ligaments confluent with the synovial membrane, such as the tibial collateral ligament and the cruciate ligaments, had to be sacrificed (Fig. 1-C).

The patient's postoperative course was uneventful and she was discharged from the Hospital on January 22, 1955, with the extremity in a cylinder cast.

The cast was removed seven weeks following surgery. The patient was last seen in August 1956. At that time, examination of the knee revealed no swelling, tenderness, or evidence of recurrence of the tumor. Extension was limited to 170 degrees with approximately 30 degrees of flexion. There was no lateral or anteroposterior instability of the knee. The patient had gained weight since her discharge from the Hospital

and her knee was painless. Two months after surgery she was able to continue her former duties as an office clerk and secretary without any handicap. For eighteen months after surgery serial chest films were negative for possible pulmonary metastases, and there was no evidence of inguinal gland involvement.

Pathological specimens were examined by Dr. E. L. Cheatle, Department of Pathology, Chicago Wesley Memorial Hospital.

The report of a microscopic examination of the patella stated: "Beneath a thin layer of compact bone and extending between the innermost bony spicules there are strands and cords of closely packed, large

FIG. 1-B

The knee joint at surgery following dislocation of the patella. The entire synovial membrane and fat pad are involved with tumorous growth.

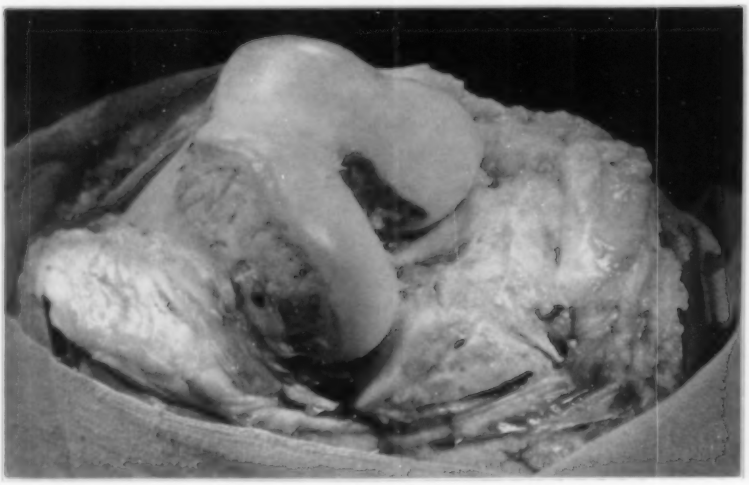

FIG. 1-C

The knee joint following surgery. Note that the cruciate ligaments have been removed and the synovial membrane has been dissected as completely as is feasible.

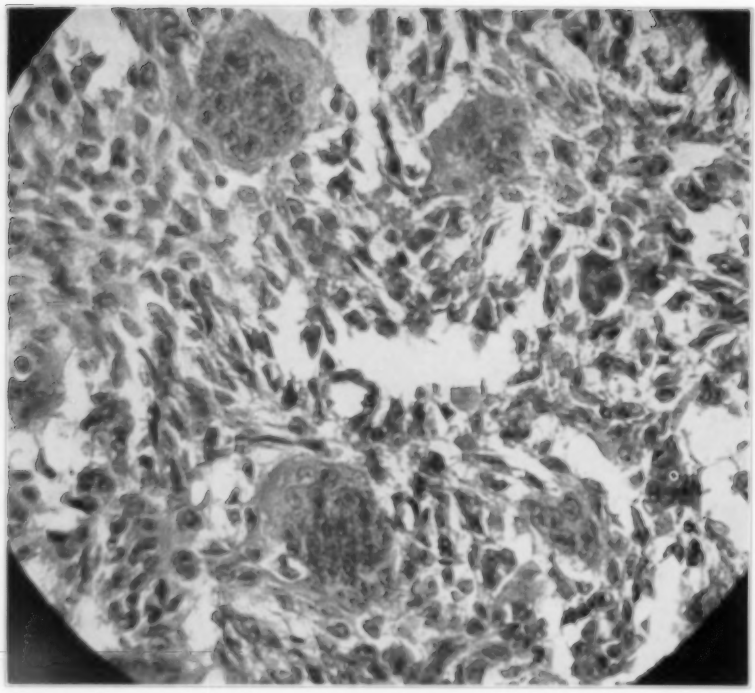

FIG. 1-D

Photomicrograph (× 645) through a section of the patella showing numerous giant cells with increased cellularity.

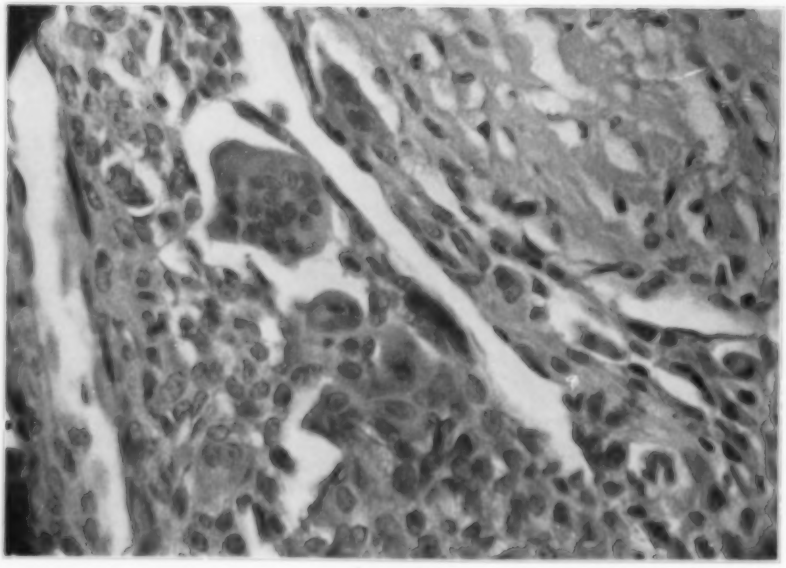

FIG. 1-E

Photomicrograph (× 645) of a section of the synovial membrane showing secondary invasion by multinucleated giant cells and stromal cells similar to those seen in Fig. 1-D.

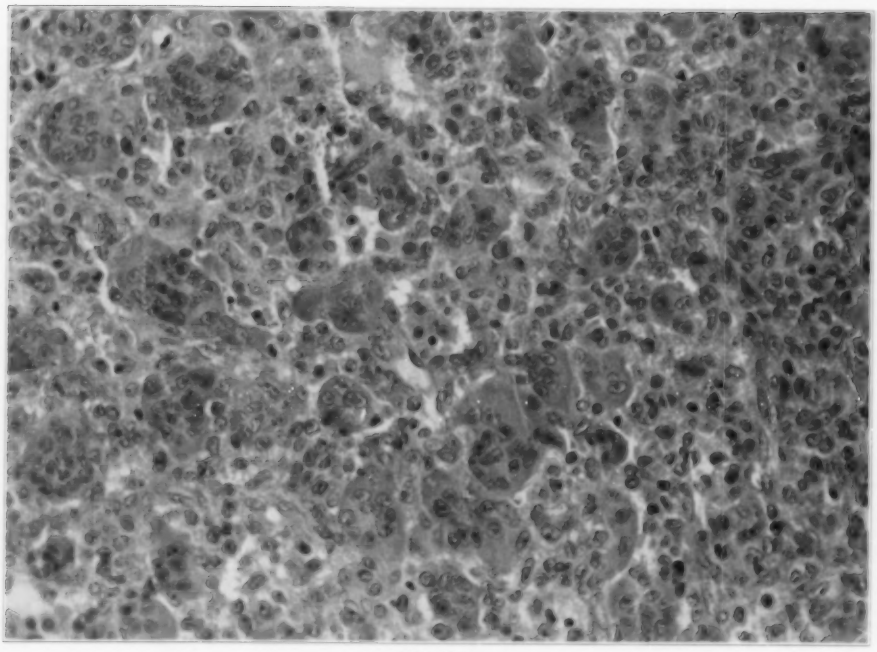

FIG. 2-A

Photomicrograph (× 330) of tissue taken at the time of initial curettement showing large numbers of multinucleated giant cells and spindle-shaped cells with occasional mitotic figures.

spindle cells. Numerous multinucleated giant cells are seen throughout this tissue. All of the spindle-shaped cells have large, vesicular, pale-staining nuclei. In some places there is slight nuclear variation. Additional sections are taken through the bone and cartilage of the patella. These reveal that strands of tumor tissue within the marrow spaces of the patella extend in a few areas through the outer bone into surrounding fibro-adipose tissue."

The report of a microscopic examination of synovial tissue stated: "Sections reveal a tumor composed of closely packed stromal cells having round to slightly ovoid basophilic nuclei with basophilic nucleoli and slight portions of chromatin. Occasional mitotic figures can be seen. However, none show bizarre or unusual changes. Numerous large giant cells are seen throughout all the sections, having up to twenty or thirty nuclei in every cell. Dense eosinophilic fibrous connective tissue appears to act as a stroma for the tumor cells."

Pathological diagnosis was giant-cell tumor of the patella with extension to the synovial membrane and fat pad (Figs. 1-D and 1-E).

The tissue slides were reviewed by Dr. Clinton L. Compere, who agreed with the diagnosis.

This case was presented at the Orthopaedic Staff Conference of Chicago Wesley Memorial Hospital; it was the unanimous decision of those present that the patient should not be given x-ray therapy in combination with surgery.

CASE 2. P. S., a white girl, fifteen years old, was admitted to Evanston Hospital on August 16, 1949, with a chief complaint of pain and swelling in the left knee. Three years prior to admission the patient had sustained a fall from a bicycle, badly abrading the skin overlying the left knee. The abrasion healed promptly. The patient was asymptomatic until January 1949, when the knee began to hurt. The patient had an antalgic limp and the knee gave way several times during her activities in the gymnasium. She was seen by her family physician, who made roentgenograms of the knee and told her that the patella was "soft" and needed an operation. The patella was curetted elsewhere on March 19, 1949. Microscopic examination of the removed tissue revealed a giant-cell tumor (Fig. 2-A). Motion of the knee was resumed one week after operation. Swelling of the knee persisted and the patient was bothered with intermittent pain. On August 10, 1949, the patient again fell and struck her left knee, which aggravated the pain and swelling. Roentgenograms made on August 13 showed evidence of continued tumor growth within the patella (Fig. 2-B).

Positive findings in the examination were limited to the left knee which appeared to have had an acute fracture of the patella. There was considerable swelling and discoloration associated with pain and limitation of motion.

A patellectomy was done on August 17, 1949. Tumor tissue which was found invading the patellar tendon and the joint capsule was removed as completely as possible (Fig. 2-C).

Pathological specimens were examined by Dr. R. E. Lininger and Dr. J. C. McCarter, Department of Pathology, Evanston Hospital Association.

The report of a microscopic examination of the patella stated: "Sections reveal almost complete destruction of the trabeculations and the cortex of the patella by the highly cellular tumor. The latter consists of numerous multinucleated giant cells, between which are oval to spindle-shaped cells which vary slightly in size, shape, and staining. There are occasional mitotic figures. The tumor invades the knee joint through the bone and into the patellar tendon."

The report of a microscopic examination of joint tissue stated: "Twenty sections of the soft tissues were examined. A number of these show definite tumor tissue invading the soft tissue, particularly on synovial surfaces. One or two small, thin-walled vessels, presumably lymphatics, contain tumor tissue."

Surgical ablation of the limb was recommended by those who examined the tumor tissue microscopically because of the frank sarcomatous changes.

FIG. 2-B

Roentgenogram made five months after curettement showing continued invasion of the patella by the tumor.

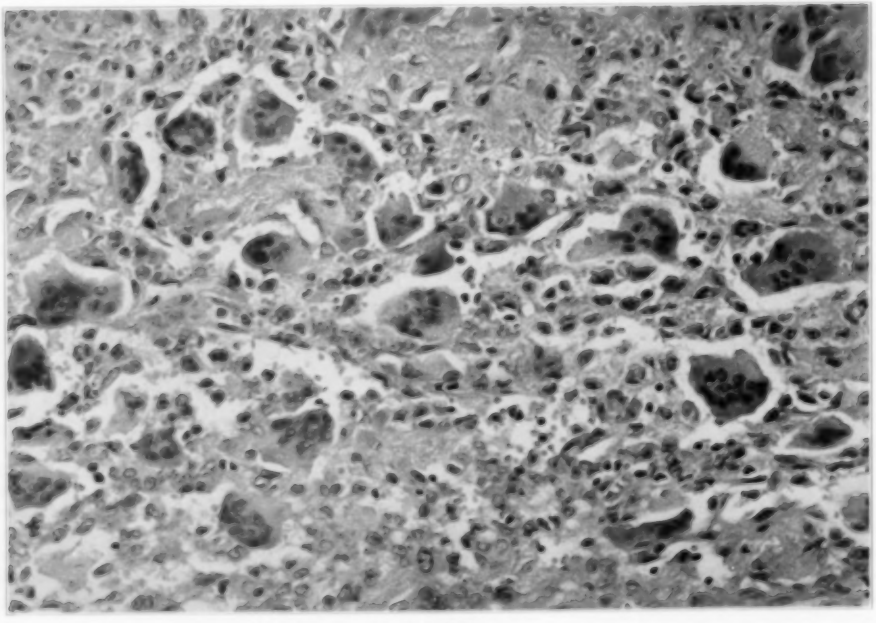

FIG. 2-C

Photomicrograph (× 330) of synovial membrane showing definite involvement by tumor, with the same histological appearance as in Fig. 2-A.

Pathological diagnosis was giant-cell sarcoma of the patella with extension to the soft tissues of the knee joint.

Microscopic sections of the tumor were examined by Dr. Granville Bennett and the late Dr. D. B. Phemister. Both were of the opinion that the tumor was a giant-cell tumor showing sarcomatous change. For this reason, a mid-thigh amputation was done on September 2, 1949.

Serial chest films have continued to be negative for pulmonary metastases.

The patient was fitted with a suction-socket prosthesis and when last seen, more than six years after amputation, was apparently well.

DISCUSSION

Including these two, there are reports of twenty-eight cases of giant-cell tumor of the patella in the literature, the latest being as recent as January 1955 [1, 2, 4, 6, 7, 9, 10]. Of these twenty-eight, seventeen patients were females and eleven were males, with an age range from fifteen years to forty-five years, the average being 28.5 years. The majority of the patients gave a history of trauma prior to or coincidental with the onset of symptoms. In view of the small number of cases reported in the literature as compared with the many cases of trauma to the patella which must occur every day, it is doubtful that injury plays any role whatever in the etiology of this lesion. However, a patella invaded by an osteolytic lesion, such as a giant-cell tumor, would be more liable to fracture. Obviously, a crack through the articular surface of the patella would allow tumor cells to infiltrate into the joint and to start foci of secondary invasion by direct extension. This should not necessarily be regarded as evidence of malignant degeneration of the giant-cell tumor of the patella.

Of the twenty-six cases of giant-cell tumor of the patella found in the literature, three were treated by amputation, six by curettement, one by partial excision of the patella, and the remainder by total excision of the bone. There were three recurrences, all of which occurred following curettement. Two of the patients were reported as being well following further curettement. The third patient died with metastases to the lungs six years after discovery of the lesion [4].

In twenty-five of these cases no extension of the tumor to the surrounding soft tissues was reported. The one exception was that in which the patient died six years after discovery of the lesion.

When the tumor is confined to the patella, total excision should be done since the patella is a bone easily resected and the tumor can be completely removed. Patients having extension of the lesion to surrounding soft parts must be treated according to the microscopic appearance of the tumor. Amputation is indicated when there is evidence of malignant degeneration.

The use of roentgen therapy raises a controversial question. However, the consensus of several bone pathologists is that it should not be used in combination with surgery. The reasons for this opinion are not entirely clear [3, 5, 8].

CONCLUSIONS

Giant-cell tumors of the patella are rare. Twenty-eight cases, including the two presented here, have been reported in the literature. Resection of the patella gives the best prognosis. Patellectomy should be combined with synovectomy if the joint has been invaded by the lesion, provided there is no suspicion of malignant growth.

NOTE: Acknowledgement is made to Dr. Newton C. Mead, Evanston, for permission to report Case 2.

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DISCUSSION

Congenital Talipes Equinovarus

(Continued from page 283)

correction of the inversion of the hind portion of the foot. Also in every case, we found that the navicular was still medially displaced in front of the talus. If necessary, the posterior capsule was excised and the heel cord lengthened.

The primary deforming elements we found were the leathery lacinate and deltoid ligaments; the tibialis posterior, tendo achillis, and anomalous tendons; and the fibrotic pretalar, subtalar, and posterior capsules. Prior to closing the wound, the tourniquet was released, and the degree of correction compatible with good circulation was noted.

If a foot with a resistant deformity provides an adequate weight-bearing structure but full correction has not been obtained, bone reconstruction can be considered at the age of nine or ten years.

The average age of these seven patients was three, and all but one had undergone tenotomy and fasciotomy previously and had been periodically immobilized in plaster casts until the time of operation. Our plan of treatment is designed to obtain satisfactory correction at an early age, that is, shortly after walking has begun. The procedure is not without risk, however. In six of the patients very gratifying results were obtained, but in the seventh circulatory complications developed, resulting in the loss of a portion of the foot.

Dr. Bell (closing): I would like to emphasize that this paper was not presented with the intent of advocating any particular procedure as the method of choice in the treatment of early uncomplicated deformities. Rather it is a descriptive analysis of the results in a group of patients, for the most part treated late or inadequately, seen in a rural orthopaedic program which was started over forty years ago by Dr. Lovett and continued by Dr. Ober and his associates. Although the number of cases is small, the long period of follow-up has made us feel that this group of operative procedures has been worth presenting.

The fifty-three patients treated by operation were drawn from a total group of about 150 patients. The proportion of patients treated by operation in this group is thus extremely high. Since, however, the types of deformities in the total group were not usual, we do not feel that this circumstance should be interpreted to indicate that our opinions are significantly at variance with those of the proponents of conservative treatment.

Osteoclastoma of the Femur

Report of a Case

BY LUIZ LEAO, M.D., RIO DE JANEIRO, BRAZIL

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On June 30, 1952, P. J. C. (I.A.P.I. cc. 6531479), a colored boy, nineteen years old, was admitted to the Orthopaedic Service of the Brazilian Red Cross Hospital.

In January of that year the medial aspect of his left thigh had begun to ache. At first he had thought that this ache was related to an injury previously sustained in the region of his knee. In March, however, he had noticed a painful swelling in the thigh. This swelling had grown rapidly and had soon interfered with the movement of his knee, affecting his walking. He had lost twenty pounds in five months.

The physical examination revealed a tumor in the anteromedial aspect of the distal fourth of the left thigh. The tumor had no clear limits and was extremely painful to touch. It was firmly fixed, had a smooth surface, seemed to consist of bone, and was joined to the femur. The range of flexion in the knee, which was also involved, was 25 to 118 degrees. Palpable ganglia were present in the inguinocrural region. During the last weeks before his admission to the hospital, the pain had been continuous, increasing at night and making it difficult for him to sleep.

The laboratory examinations revealed the following findings. Hemogram, normal. Sedimentation rate (Westergren): first hour, twenty-two millimeters in one hour; second hour, fifty-three millimeters in one hour; erythrocyte sedimentation rate (Katz formula), 24.2 millimeters in one hour; serum calcium, 10.6 milligrams per 100 milliliters; serum phosphorus, 5.3 milligrams per 100 milliliters; alkaline phosphatase, 2.8 Bodansky units; total protein, 6.0 grams per 100 milliliters (albumin, 3.7 grams; globulin, 2.3 grams); albumin to

Fig. 1

Preoperative roentgenograms made July 12, 1952. Rupture of the antero-internal portion of the femoral cortex is shown.

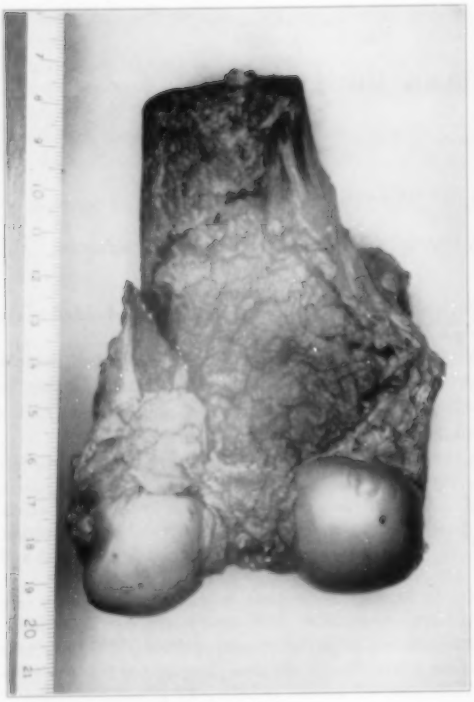

FIG. 2

FIG. 3

Fig. 2: Specimen obtained at operation. Note the fracture of the femur and the invasion of the soft tissues.

Fig. 3: Postoperative roentgenogram made July 20, 1952. One end of the autogenous cortical graft has been inserted into the medullary canal of the femur and the other end has been fixed to the proximal end of the tibia. Vitallium screws have been used to obtain fixation.

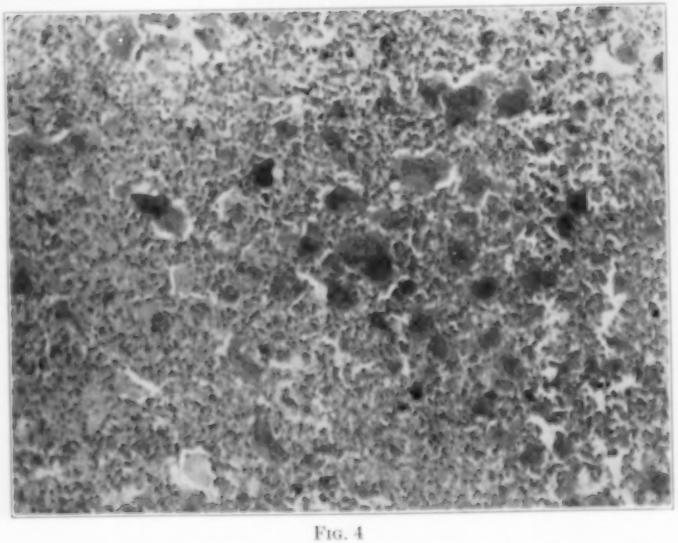

FIG. 4

Low-power photomicrograph (hematoxylin and eosin) showing the cellular stroma and the numerous giant-cells.

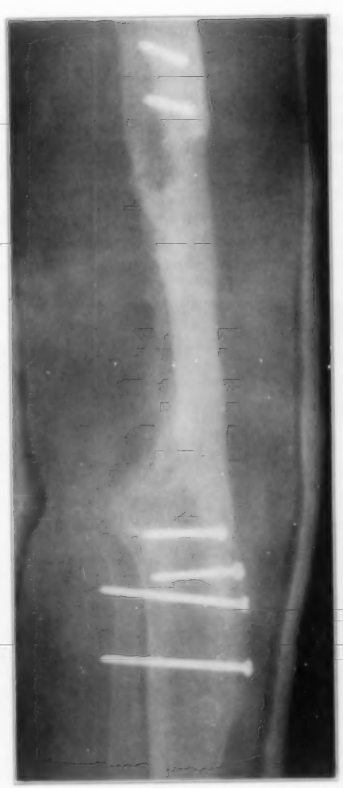

FIG. 5

FIG. 6

Fig. 5: Roentgenogram made July 1953, one year after the operation; solid union of the graft is evident.

Fig. 6: Roentgenograms made July 15, 1954. The graft is still alive and is fully united to the tibia and femur.

globulin ratio, 100:63. The results of the Wassermann, Kahn, and Kline tests were negative; the coagulation and bleeding times were normal; the blood group was A, Rh positive. Analysis of the stool revealed eggs of hookworm, *Ascaris lumbricoides*, and *Trichuris trichiura;* the results of a qualitative and quantitative analysis of the urine and the sediment were normal.

The roentgenographic examination (Fig. 1) revealed an osteolytic tumor involving the entire distal epiphysis of the femur. The anterior and interior portions of the cortex were expanded and, at various points, broken. Large radiolucent areas were crossed by rough spicules of bone.

Because of the systemic response of the patient and because of the painful symptoms, the roentgenographic appearance, and the rapid growth of the tumor, it was thought that sarcomatous degeneration had occurred. Surgery was accordingly carefully planned, and permission was obtained from the patient's family to sacrifice the extremity if malignant growth was found.

Following the general examination and with the internist's authorization, the operation was performed on July 18, 1952. A general anaesthesia, consisting of a mixture of gases, was used, and a pneumatic tourniquet was applied to the upper portion of the limb. A longitudinal incision was made on the anterior aspect of the thigh over the highest portion of the tumor. A small fragment was removed with an electric saw for frozen section and immediate examination. The tumor was found to be benign. Macroscopically the tumor appeared to be a soft, red-brown, rather bloody mass.

The benign nature of the neoplasm being established, the incision was extended. Large portions of the soft structures already invaded were removed, for in the larger involved areas the femoral cortex was ruptured. It was found that the extent of the lesion was far greater than had been indicated by the roentgenograms. The knee itself was involved, and the articular cortex was ruptured. In order to remove the epiphysis and the involved portion of the femoral diaphysis, the bone was resected by means of an electric saw at the junction of the middle and distal thirds (Fig. 2). Special precautions were taken to isolate the popliteal neurovascular bundle, a procedure that was particularly difficult because of the invasion of the soft tissues.

A few millimeters below the articular surface, the entire tibial plateau was resected. The incision was then extended to three inches above the ankle interline. With the circular electric saw the tibia was split longitudinally, the anterior half being used to replace the removed portion of the femur. The distal end of the graft was inserted into the medullary canal of the resected femur and the proximal end was placed against the proximal end of the tibia. In order to fix the graft and to provide more stability, several Vitallium screws were used (Fig. 3). The spongy tissue obtained from the tibia was placed about the cortical graft in the form of a pyramid, the base of this pyramid being at the distal end of the graft. All the soft parts were carefully sutured, without drainage. A plaster-of-Paris cast was applied from the pelvis to the tip of the toes.

A histological study was carried out during the course of the operation. Frozen sections, later embedded in paraffin, were made, and the following findings were reported. The tumor was finely granular and had vague limits. The chief cells were giant cells with rose-colored cytoplasm and numerous nucleoli. The stroma

FIG. 7

Follow-up photographs made January 5, 1956, three and a half years after the operation. At this time full weight-bearing caused no discomfort. There was a minor cavus deformity of the left foot.

had a reticular appearance and was very cellular. Mitotic division was evident. The final diagnosis was giant-cell tumor (Fig. 4).

The postoperative course was complicated by icterus (diagnosed as icterus hemolyticus by the internist) and by paralysis of the toes. The paresis disappeared twenty days after the operation.

On January 5, 1953, with the patient on the operating table, the original plaster cast was removed and a new light cast was applied from the toes to the base of the thigh. Ambulation without weight-bearing was permitted. Control roentgenograms showed incorporation of the graft with the femur and tibia. Clinically it also appeared that the graft was firm.

A new cast, which allowed ambulation with weight-bearing, was applied on April 4, 1953. Follow-up by means of roentgenograms was continued (Fig. 5), and in November 1953, immobilization was discontinued and normal walking allowed.

On July 15, 1954, two years after removal of the tumor and plastic reconstruction of the femur, the case was reviewed. The cosmetic result was considered excellent, there being no shortness of the left limb. From a functional standpoint the equality in limb length was an inconvenience, however, for the rigidity of the limb made walking difficult, a condition which could be best ameliorated by increasing the length of the opposite limb through the use of a higher heel. Roentgenograms showed perfect incorporation of the graft,

with integration of the trabeculae of the host bones and graft and with organization of a continuous medullary canal from the femur to the tibia (Fig. 6). There was a greater apposition of new bone near the tibia, as if an attempt was being made to reproduce the femoral condyles.

On January 5, 1956, three and a half years after the operation, another follow-up examination was made. The patient reported that he suffered no pain or discomfort in his work as a plumber despite the fact that he had to assume many different positions. He was physically and psychologically adjusted to his disability (Fig. 7). There was no evidence of recurrence of the tumor, and the roentgenograms also showed less sclerosis, greater trabecular continuity, and further development of medulla in the graft (Figs. 8-A and 8-B).

DISCUSSION

Observations made in this and similar cases with regard to the evolution of the tumor and its effect on the involved structures led us to believe that the conception of osteo-

FIG. 8-A

FIG. 8-B

Figs. 8-A and 8-B: Roentgenograms made January 5, 1956, showing less sclerosis, better trabecular continuity, and further development of medulla in the graft. There is no evidence of recurrence of the tumor.

clastoma as a benign neoplasm should be modified. At least this conception does not seem to apply to those giant-cell tumors which are rapidly destructive and invasive.

A discrepancy has frequently been noted between the clinical and histological aspects of the tumor; in such cases, although the clinical behavior of the tumor is truly malignant, with irremissible involvement of the affected structure, the pathologist cannot find sufficient evidence to support a diagnosis of malignant growth. Experience has shown that in a remarkable number of the cases in which the therapy is late, the tumor undergoes sarcomatous degeneration. The present case, in which there was rapid development of the tumor with serious injury to the thigh, is an excellent example of a histologically benign tumor co-existing with clinical malignant growth.

The problem of therapy is very serious and requires careful study. It is well known that roentgen therapy does not always result in healing, especially in cases of large tumors, and there are a number of objections to this method of treatment. Reports of cases in which irradiation was followed by sarcomatous degeneration and metastasis have not been rare. Furthermore, it is sometimes impossible to control the tumor even with large

doses of roentgen rays, and it also may happen that even if the tumor is destroyed, new tumors will develop and expand in the adjacent areas. Frequently the tegument and other irradiated structures involved by the tumor will undergo serious alterations and ulcerate.

The plastic operations attempted have resulted in failure, sometimes making secondary amputation necessary.

Surgical eradication of the tumor seems to offer better results [2]. In this procedure it is necessary to by-pass the involved area and to make the cut through healthy tissue. When extensive resection of bone is done, skeletal reconstruction becomes a problem. In one case of giant-cell tumor of the femur in which resection had been done, Compere used both autogenous tibial-bone and bone-bank grafts and maintained stability by means of a long Küntscher's pin. In our case a thick autogenous tibial graft provided both support (cortex) and material for osteogenesis (cancellous bone). The anterior half of the tibia, including the ridge, was strong enough to sustain the soft structures of the thigh and at the same time served as an excellent mold, thus facilitating the apposition of new bone. The spongy tissue distributed about the graft also facilitated the apposition of new bone. The main cause of our success, however, was, we believe, the careful excision of all the involved tissue, for in this way the possibility of recurrence was eliminated.

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Traumatic Arteriovenous Aneurysm of the Foot

BY CAPTAIN HAROLD M. BRODER AND CAPTAIN JOHN H. CAUGHRAN, *Medical Corps, United States Air Force*

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The following report describes an arteriovenous aneurysm of the medial plantar vessels which complicated a combined fracture of the outer aspect of the calcaneus and the tip of the lateral malleolus. No missile entered the area, and there were no bone spicules present to explain its occurrence. We have been unable to find a recorded parallel. In a personal communication, the Emory University surgical group stated that they had not encountered a similar case in their wide experience with aneurysms[1]. Arteriovenous aneurysm is a well recognized complication of penetrating wounds, and has been known to follow perforation of blood vessels by bone fragments after fractures[7]. A few cases have resulted from damage during surgical procedures on the foot[2,3,4,6,8].

On July 28, 1955, C. W., a twenty-year-old airman, fell from the loading elevator of a bomber approximately twenty-five feet to the ground, his right foot taking the full force of his landing on a concrete runway. No penetrating wound resulted nor did he note an obvious deformity of the ankle or foot. No other significant injury was sustained. Emergency treatment consisted in analgesia, elevation, and splinting. He was transported by air evacuation to the 3275th United States Air Force Hospital, Parks Air Force Base, California, arriving four days after the injury. Examination revealed a markedly swollen right foot and ankle with a large bleb over the medial malleolus. Ecchymosis was present over the entire extremity below the knee. The foot was warm. Inability to palpate the anterior and posterior tibial pulses and the apparent absence of

FIG. 1-A

FIG. 1-B

Figs. 1-A and 1-B: Note displaced fragment from the lateral aspect of the calcaneus, and the small fragments present under the tip of the lateral malleolus.

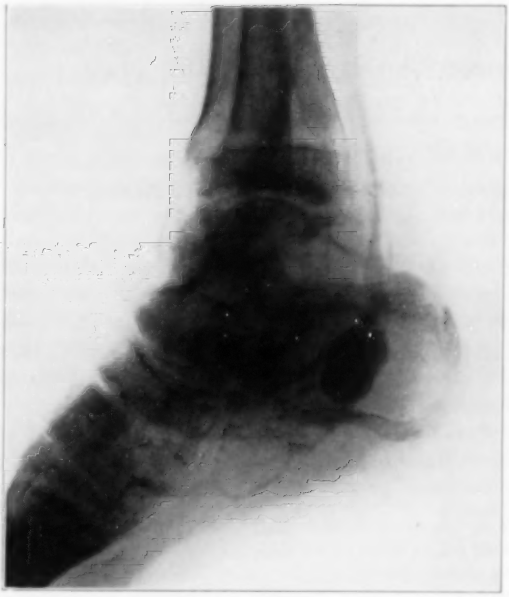

FIG. 2

Arteriogram showing position of aneurysm.

motor power and sensation in the foot was attributed to the extreme swelling. Roentgenograms were made (Figs. 1-A and 1-B).

Treatment consisted in application of a compression dressing, immobilization in a posterior plaster mold, elevation, and the application of ice packs. During the ensuing few days, as swelling gradually subsided, the anterior tibial pulse became palpable, and motor and sensory function returned to the foot. Nine days following admission (two weeks after injury), the displaced lateral fragment of the calcaneus was molded under anaesthesia and a circular toe-to-groin cast applied. Approximately two weeks later (one month after injury), the patient began to complain of a mild, throbbing discomfort on the medial aspect of the heel. When the plaster was removed a month later (three months after injury), a pulsating mass measuring two inches in diameter was revealed inferior to the medial malleolus. Aspiration yielded arterial blood under pressure. The skin of the involved foot was warmer than that of the well foot. The anterior tibial pulse was greater than normal in volume. The posterior tibial pulse was not palpable through the induration and swelling about the medial malleolus. A continuous bruit, accentuated during systole, was heard on auscultation. Compression produced no alteration in blood pressure or pulse rate. Blood pressure and heart size were normal. An arteriogram by femoral injection of twenty-five cubic centimeters of urokon sodium was made, with readings taken at eight and ten seconds (Fig. 2).

Surgery was performed under pneumatic tourniquet control on October 14, 1955. The posterior tibial neurovascular bundle was exposed through a curved incision and traced beneath the abductor hallucis into the sole of the foot. The deltoid ligament appeared to be intact. The aneurysm, which measured two by one by three-fourth inches, and its vessels of entry and exit were isolated (Figs. 3-A and 3-B). The vessels entering the sac were an enlarged medial plantar vein, a short, stout trunk from the medial plantar artery, and the medial malleolar branches of the medial plantar artery and vein. The lateral plantar vessels were uninvolved. Two thin vessels of exit were present. The sac was removed after ligation and division of its branches. The tourniquet was then released and the lateral plantar vessels were observed to fill. A plaster boot was applied after closure of the wound. Microscopic examination of sections of the aneurysm revealed a fibrous-tissue wall containing no muscle fibers and a lining consisting of flattened cells. Healing occurred uneventfully, and unsupported weight-bearing was resumed two weeks after the surgery. The patient was returned to full duty on November 21, 1955, approximately four months after the injury. At this time the anterior tibial pulse remained exaggerated and the posterior tibial pulse was present, but diminished.

DISCUSSION

Of the two principal vascular channels which enter the foot, the posterior is most frequently injured. The closed space under the flexor retinaculum renders the posterior tibial vessels easily liable to damage by extruded or displaced fracture fragments from the talus. In outward dislocations of the foot, the medial malleolar branch of the anterior tibial artery is frequently torn when the parent trunk is swept laterally with the foot [5].

The case reported could probably be diagnosed as a temporary eversion type of subluxation of the foot, which could conceivably have torn the involved vessels. The presence of a shearing-type fracture of the outer aspect of the calcaneus combined with comminution of the tip of the lateral malleolus (Figs. 1-A, 1-B, and 2) supports this hypothesis.

There is an important distinction between true arterial aneurysm and arteriovenous aneurysm, from the point of view of therapy. In arteriovenus aneurysm, one may observe a continuous bruit accentuated during systole on auscultation and a slowing of the pulse,

with a rise in blood pressure on compression. Arterial aneurysm, on the other hand, occasionally presents a systolic bruit only. Proximal ligation may suffice for treatment in arterial aneurysm, but ligation and excision are necessary in the arteriovenous aneurysm.

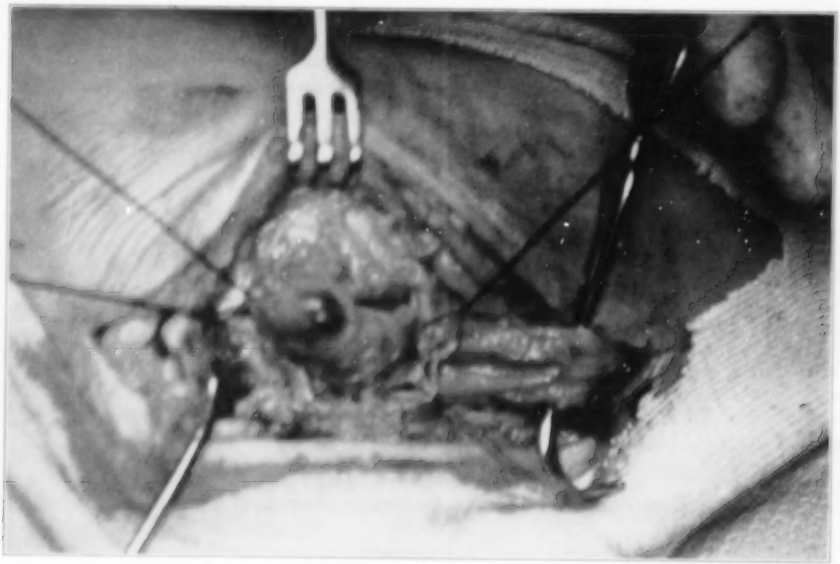

FIG. 3-A

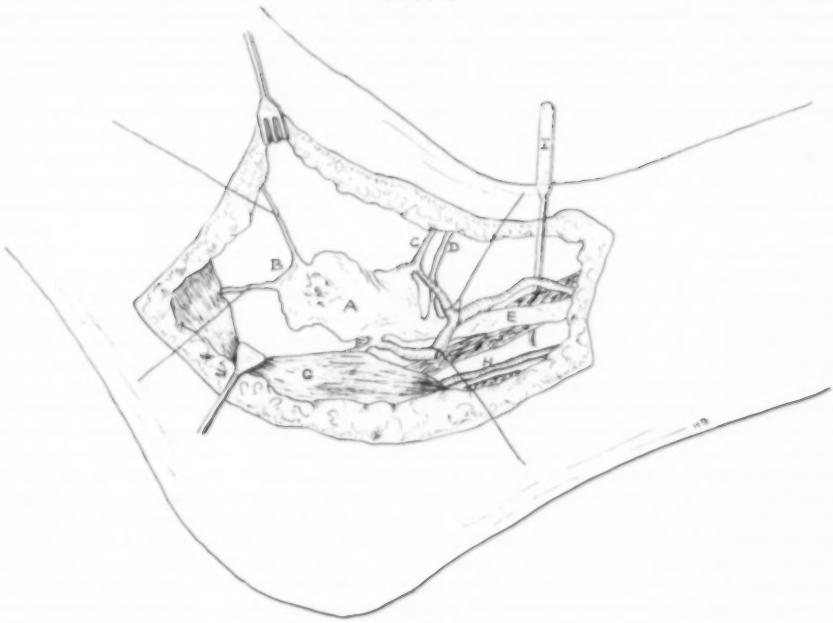

FIG. 3-B

Figs. 3-A and 3-B: Photograph of operative exposure and diagrammatic representation. *A*. Aneurysm sac. *B*. Two small vessels of exit. *C* and *D*. Branches of medial malleolar artery and vein entering sac. *E*. Medial plantar vein entering sac. *F*. Branch of medial plantar artery entering sac. *G*. Abductor hallucis muscle. *H*. Lateral plantar neurovascular bundle. *I*. Probe under medial plantar neurovascular bundle.

Unless excision is carried out, blood will continue to reach the aneurysmal sac by way of the collateral circulation.[7] On microscopic examination, muscle fibers are found in the wall of the arterial aneurysm but are absent in the arteriovenous aneurysm.

Unless circulatory embarrassment is threatened by an enlarging hematoma in treatment of arteriovenous aneurysm, surgery should be deferred for two to three months in order to allow the development of an adequate collateral circulation. The lesion may meanwhile be further studied, as in this case, by arteriogram. Surgical treatment consists in the isolation of the vessels of entry and exit, followed by ligation and excision. Excellent results may be expected.

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Aneurysm of the Popliteal Artery from Perforation by a Solitary Exostosis of the Femur

A Case Report *

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Aneurysm produced by an exostosis perforating an artery is extremely rare, yet reports of two different cases have appeared in the literature during the past few years. Review of the previous literature disclosed no report of such an occurrence. In both of the cases described, the aneurysm occurred in the popliteal artery, and in each instance the patient had multiple exostoses involving other bones as well as the femur. In neither instance was there a specific violent episode of trauma preceding the onset of symptoms. The aneurysm in the case reported here also occurred in the popliteal artery, but differed from the other two in that it resulted from a solitary osteochondroma with symptoms following specific trauma to the area.

A white man, twenty-three years old, was admitted to the Hospital on March 21, 1955, with a diagnosis of osteochondroma of the lower end of the right femur. He complained of a painful mass in the posterior aspect of the distal portion of the right thigh. He first had symptoms referable to this area in November 1951, when he injured his right knee in a fall from a ladder. At that time there was swelling of the knee and the distal portion of the thigh which gradually subsided following rest. Pain was initially severe and persisted intermittently to a mild degree with radiation to the right calf. During the two years immediately preceding his admission, the pain had been present chiefly after prolonged standing or walking. He described episodes of "giving way" of the right knee, and, one month prior to admission, a collapse of the knee while walking. This was followed by swelling of the knee and the popliteal area with intensification of pain. The knee swelling subsided but the popliteal mass persisted. Several days prior to admission the patient noted pulsation of this mass.

Physical examination revealed a young man apparently in robust health. Pulse, temperature, respiration, and blood pressure were normal. There was a soft, ovoid, non-tender mass measuring eight by six centimeters situated in the region of the apex of the right popliteal area slightly medial to the mid-line. The overlying skin was soft, non-adherent, and warm. There was a distinct pulsation of this tumor, and a clear bruit could be heard over its center. Both pulsation and bruit ceased on compression of the femoral artery. Femoral, popliteal, posterior tibial, and dorsalis pedis pulses were full and equal. There was no venous engorgement distal to the tumor and there were no signs to suggest an intra-articular lesion of the right knee.

Roentgenograms of the right femur and knee revealed a large broad-based exostosis of the posteromedial aspect of the distal portion of the femur with a pointed spur projecting, spear-like, medially at a level approximately ten centimeters above the joint line and corresponding to the center of a soft-tissue mass overlying this spicule (Fig. 1). A roentgenographic survey of other bones including tibiae, fibulae, femora, and both humeri revealed no other exostosis. An arteriogram of the right femur revealed an ovoid sac measuring seven by four centimeters overlying the prominent spur and displacing the popliteal artery backward (Fig. 2). A simultaneous bilateral puncture of the femoral vein revealed equal venous pressures. Samples of blood from each vein showed oxygen saturation of 82 per cent on the right and 74 per cent on the left. The carbon dioxide combining power was 49.4 volumes per cent on the right and 53.3 volumes per cent on the left. The significance of these differences was not apparent since the mass presented none of the characteristics of an arteriovenous aneurysm and no venous communication was found at operation.

Operation was performed on April 6, 1955, under general endotracheal anaesthesia, with the patient in a prone position and without the use of a tourniquet. Through an eight-inch posteromedial curved incision the aneurysmal sac was readily identified lying deep to the popliteal fascia (Fig. 4). The femoral artery above

* The statements and conclusions published by the authors are a result of their own study and are not to be construed as reflecting the policy of the United States Navy or a part thereof.

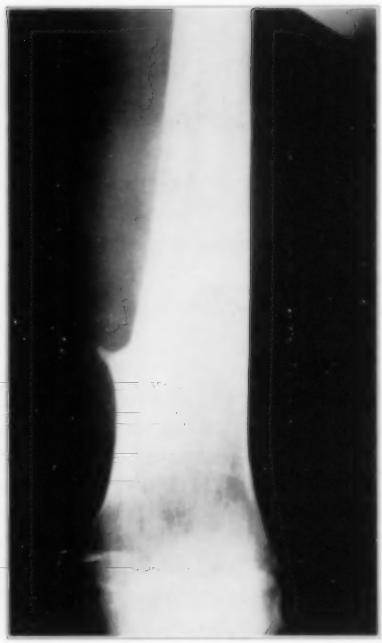

FIG. 1-A

FIG. 1-B

FIG. 2

FIG. 3

Figs. 1-A and 1-B: Preoperative roentgenograms showing broad-based exostosis with sharp spur pointing posteromedially.

Fig. 2: Preoperative arteriogram showing aneurysmal sac overlying the exostosis and displacing the overlying popliteal artery.

Fig. 3: Postoperative arteriogram showing filling of the femoral and popliteal arteries with no evidence of constriction at the site of the arterial repair.

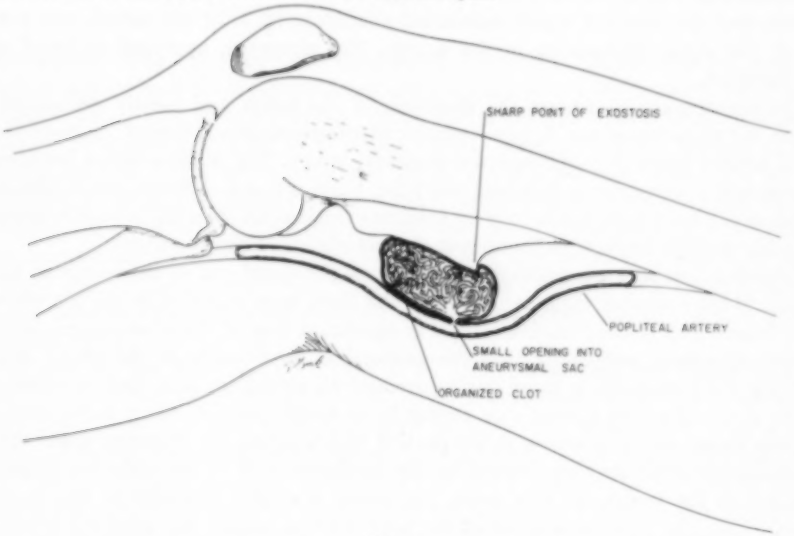

Fig. 4

Diagram of the operative findings. Note that the wall of the aneurysm is continuous with the wall of the popliteal artery.

and the popliteal artery below the sac were isolated and controlled as the first step. The popliteal vein, popliteal nerve, and common peroneal nerve were dissected free and were retracted. As indicated by the arteriogram, the popliteal artery was lifted from its normal position on the floor of the popliteal fossa by the underlying sac which was oval in shape and measured eight centimeters in its longitudinal and greatest diameter. The overlying artery was closely adherent to the sac but was freed by careful dissection, revealing a small communication between the artery and the sac. The genicular arteries were preserved. The artery above and below the sac was then clamped with Potts clamps and the sac was opened, revealing it to be filled with a well organized clot. The sac was removed and the five by three millimeter opening in the artery was closed with a continuous 00000 atraumatic silk suture. Good pulsations, no leakage, and no apparent constriction were present after removal of the clamps. The deep wall of the sac was closely adherent to the underlying exostosis. The irregular surface of the exostosis, along with a large portion of the sessile base, was removed with an osteotome. Gelfoam was placed over the large area of raw bone and the wound was closed in layers, fine cotton interrupted sutures being used. Peripheral pulsations were normal immediately after the operation. The patient's recovery was uneventful.

An arteriogram of the right femur was made on May 19, 1955; this showed excellent filling of the femoral and popliteal arteries and no evidence of constriction at the level of the arterial repair (Fig. 3). The collateral arteries in the area were well filled and abundant. A portion of the base of the osteochondroma remained, but it was not considered to be significant because of the patient's age and its smooth configuration.

After gross and microscopic pathological examination the material removed was reported to be a true aneurysm containing thrombus undergoing organization and osteochondroma. A small remnant of the cartilaginous cap of the osteochondroma was present.

The patient was returned to full duty on May 24, 1955, at which time he was asymptomatic. The peripheral pulsations in his lower extremities remained normal and he was able to participate in vigorous exercise without difficulty. Prolonged ambulation or standing no longer caused discomfort or pain.

DISCUSSION

It is interesting to speculate on the probable mechanics of the production of the aneurysm. That the sharp spicule of bone penetrated the popliteal artery can scarcely be

denied, but the moment of occurrence is difficult to establish. The specific injury which occurred in 1951 may have broken the stalk of a solitary osteochondroma, causing penetration of the first portion of the popliteal artery by the resulting sharp spur. The osteochondroma up to this point was the chief source of symptoms, but thereafter the pulsating aneurysm succeeded in distorting the exostosis so that it no longer resembled the solitary osteochondroma with its characteristic cartilaginous cap. The appearance of the aneurysm indicated that the incident which antedated admission by only one month was not the cause of the initial perforation of the artery. The aneurysm appeared to be of much longer duration.

The arteriogram confirmed the diagnosis of the lesion and clearly delineated the extent of the aneurysmal sac. A postoperative arteriogram demonstrated the re-establishment of normal blood flow through the popliteal artery. The differentiation between an aneurysm and a quiescent or inflamed overlying bursa was not difficult, and a mistake in diagnosis could have been made only by careless examination since the pulsatile character and readily audible bruit were prominent characteristics of the aneurysm.

Osteochondromata are commonly situated at the distal end of the femur at the attachment of the adductor magnus. Although the three cases reported in the literature are too few from which to draw conclusions, it is significant that all three aneurysms involved the popliteal artery, suggesting that the anatomical relationship of the artery and the underlying bony exostosis is more apt to produce an aneurysm here than at other sites.

The popliteal artery is relatively mobile in its middle portion where it lies embedded in adipose tissue, but it is less so in the portion which enters the popliteal space through the osseo-aponeurotic opening formed by the tendinous arch of the adductor magnus as it attaches to the femur. At this point, the artery is closely adherent to the overlying popliteal vein. The superior arteries of the knee tend to anchor the popliteal artery, decreasing lateral mobility. It is not difficult to visualize the tenting of a popliteal artery over an osteochondroma arising at the insertion of the adductor magnus. The arteries of the knee may readily act as guys preventing the displacement of the popliteal artery to one side of the cap. Penetration of the artery could occur either by specific trauma or by prolonged small traumata of everyday activity.

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Aneurysmal Bone Cyst of a Metatarsal

A Case Report

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Aneurysmal bone cysts are not encountered frequently. Dahlin and his associates reported an incidence of twenty-six (1.3 per cent) in a series of 2,000 primary bone lesions. Lichtenstein stated that the condition is benign and is not a neoplasm at all. It is caused by vascular disturbance leading to increased venous pressure which produces an enormously dilated and congested vascular bed within the affected bone area [8]. He felt that the condition could be the result of an anomalous arteriovenous communication and that it definitely originates within bone. He rejected the theory of Geschickter and Copeland that an aneurysmal bone cyst develops as a result of a subperiosteal hemorrhage and its subsequent organization. Thompson's theory is that the condition probably represents a reparative process following some vascular disturbance about the periosteum and the surrounding tissue.

This process was described by Ewing as an aneurysmal giant-cell tumor in which, as "the result of free communication with large blood-vessels, some giant-cell tumors take the gross form of a bone aneurysm, grow to large size, occasionally yield a bruit, and are composed of many large blood spaces, filled with blood-clot, and lined by giant-cell tissue". Geschickter and Copeland considered that the process is the response to trauma of an abnormal subperiosteal osteoclastoma or giant-cell tumor, resulting in a hemorrhage, with the subsequent disturbance of the normal blood supply to the bone acting as a stimulation to the production of osteoclasts. Coley and Miller described the condition as an atypical giant-cell tumor, although they said that in some instances a diagnosis of "angioma of bone" was returned. Jaffe and Selin summarized the process as a "radiologic-pathologic" disturbance sufficiently striking to merit independent consideration, but they admitted the possibility that the lesion may be the consequence of hemorrhage, in the course of which an established benign lesion has been destroyed. They felt, however, that the original lesion is neither a giant-cell tumor nor a hemangioma. Shallow and Wagner reported a case of this lesion in a metatarsal bone.

In Lichtenstein's second report of the condition [9], he presented a description and roentgenograms of a far-advanced aneurysmal bone cyst in the bones of the foot of a thirty-year-old South Korean man. The lesion, initially the size of a lemon, expanded to a huge mass fifteen centimeters in diameter. Amputation was performed with the clinical impression of sarcoma. It was found that the process had destroyed all the tarsal bones as well as the proximal portion of the metatarsals. Besse and his associates reported twenty-three cases of aneurysmal bone cyst from the Mayo Clinic, but none were in the hands or the feet. Thomas, in a study of vascular tumors of bone, recorded a benign cystic angioma occurring in the base of the third metacarpal bone of a woman fifty-two years old. It was curetted and did not recur in the subsequent nine-year follow-up. It is possible that the condition was similar to the one described here, but Thomas did not give details of the case in his report. Thompson, in reviewing the tripartite background of this lesion, stated that, when the condition occurs in the small bones of the hands and the feet, there may be a variation of the lesion from its classic pattern as a result of the local anatomy which prevents the typical development.

Thompson stated that "in its early development the lesion produces a soft-tissue mass of increased density but without calcification or changes in the adjacent bone. The intermediate stage, during the third and fourth months, shows the gradual development

of a domelike calcified shell outlining the periphery of the tumor. As time progresses, spontaneous healing may occur, with the mass becoming ossified. . . In the flat bones and vertebrae the roentgenographic appearance is not so distinct, but the same features, — erosion of the underlying bone and extra-osseous location of the tumor mass — prevail." It is significant that in Dahlin's review of this problem roentgenographic diagnosis could have been made in sixteen of the twenty-six cases presented, although he reported only one instance. This review reported the pertinent findings to be a circumscribed area of rarefaction, a "soap-bubbled" or honeycombed appearance of the interior of the lesion, eccentric bulging of the cortex which is usually disrupted, a peripheral, delimiting, thin shell of periosteal new bone, and, in young patients, location of the lesion in the diaphysis adjacent to the epiphyseal cartilage.

FIG. 1

FIG. 2

Fig. 1: Roentgenogram showing a cystic lesion of the distal half of the diaphysis of the third metatarsal bone. The lesion measures 3.5 by 2.5 centimeters in diameter. It expands the cortex without destroying or eroding it.

Fig. 2: Roentgenogram made five months later, showing expansion of the untreated lesion during the interval.

L. S., a girl, twelve years old, was first seen on October 19, 1954, for a bone tumor of the foot. Seven months before, in April, her parents had noticed that the patient was limping and found a slight swelling of her left foot. She complained of pain in the region of the ankle. A roentgenogram made at that time showed a cystic lesion of the distal half of the diaphysis of the third metatarsal bone measuring 3.5 centimeters in length and 1.5 centimeters in greatest diameter (Fig. 1). Because the swelling and pain were subsiding, orthopaedic consultation was delayed until a month later when the child began to "drag" the foot, and again had ankle pain. At this time, it was thought that the cyst might possibly break and be resorbed and that no treatment was necessary other than observation. Again, swelling and pain subsided until August, when the swelling increased and there was a noticeable limp. The pain was now in the metatarsal arch, and it was never considered severe. A roentgenogram was made on September 12; the tumor had grown, the measurement now being 3.5 by 2.5 centimeters. The cortex had become thin and expanded, but was preserved. There was no evidence of cortical erosion or destruction (Fig. 2).

The patient's past history was non-contributory. She had had two previous traumatic incidents but neither had involved the left foot. Keloid formation had followed each of these accidents.

FIG. 3

FIG. 4

Fig. 3: There is a slight swelling over the metatarsal, about five centimeters in diameter.

Fig. 4: Roentgenogram of the untreated lesion made seven months after Fig. 1, showing a fusiform enlargement, four by two by 1.5 centimeters, of most of the metatarsal shaft. A fine bony margin is preserved around the periphery with a fine loculated internal structure.

FIG. 5-A

FIG. 5-B

Fig. 5-A: The resected third metatarsal bone measuring 7.1 centimeters in length with an average external diameter of two centimeters. The bulbous portion crepitated, but a thin shell of cortex was intact.

Fig. 5-B: The hemisected specimen showing irregular lakes and saccules filled with clotted blood. The trabeculations were composed of fibrous tissue with spicules of bone. The cortex was one millimeter thick in some areas, but it showed no gross penetration. The distal epiphyseal line was uncertainly identified and did not seem to be invaded by the lesion. The proximal one centimeter of cortex was not involved. The dilated portion of the metaphysis measured four centimeters in length and the maximum diameter was three centimeters.

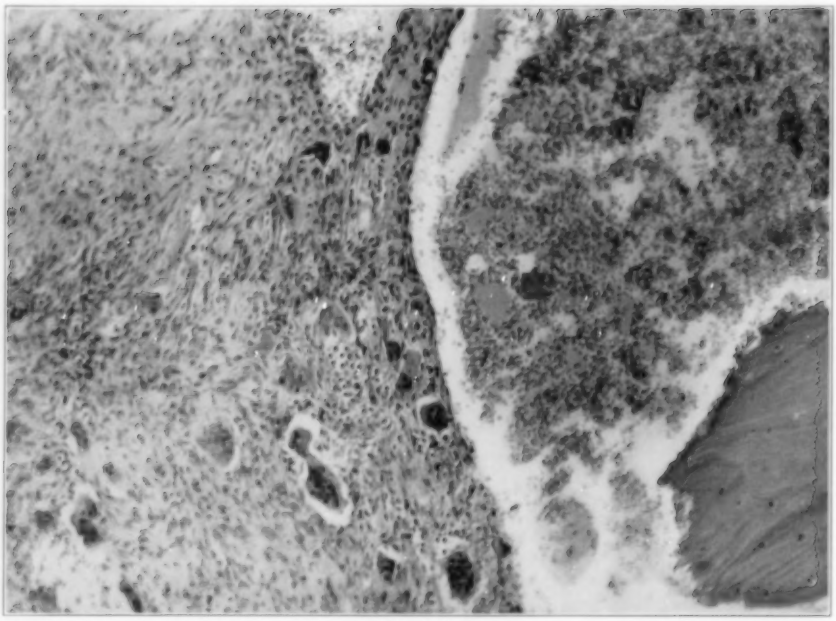

FIG. 6-A

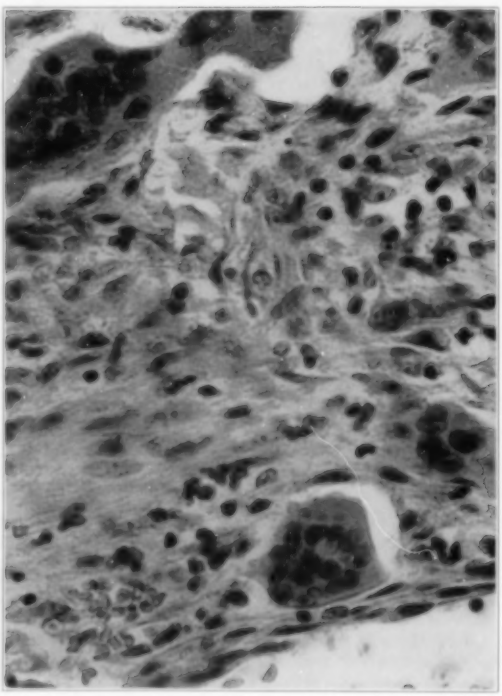

FIG. 6-B

Fig. 6-A: Photomicrograph showing a large vascular channel lined with dense bone tissue composed of young fibroblasts and numerous multinuclear giant-cells (× 80).

Fig. 6-B: A higher-power photomicrograph showing spindle-shaped stromal cells and multinuclear giant cells in the aneurysmal bone cyst. Flattened stromal cells line the blood spaces (× 360).

Physical examination was normal except in the left foot where there was obvious swelling over the involved metatarsal, covering an area of five centimeters (Fig. 3). It was questionable whether there was elevated temperature in the area. No bruit could be heard and crepitation was not definitely elicited. The bone seemed to yield to pressure, but pressure did not cause pain. After review of the roentgenograms, the diagnosis of aneurysmal bone cyst seemed most probable despite the unusual location, although the possible diagnosis of giant-cell tumor or osteitis fibrosa cystica was considered. The patient was admitted to the Memorial Cancer Center two weeks later and a skeletal survey was done in order to exclude a generalized process. Roentgenographic examination of all other bones was negative, but the third metatarsal bone showed that there had been rapid progression in the process characterized by a general expansion, a fine bony margin still being preserved with a fine loculated internal structure. The entire appearance of the lesion was consistent with an angioma of bone. There was no evidence of soft-tissue angioma. Measurements were then four by two by 1.5 centimeters (Fig. 4).

Laboratory studies revealed the following: hemoglobin, 11.5 grams per 100 cubic centimeters; white blood cell count, 6,300 per cubic milliliter with 60 per cent polymorphonuclear neutrophils, 4 per cent monocytes, 5 per cent eosinophils, 31 per cent lymphocytes; serum calcium, 9.1 milligrams per 100 cubic centimeters; serum inorganic phosphorous, 4.9 milligrams per 100 cubic centimeters; alkaline phosphatase, 8.2 Bodansky units (3.5 to 12 units is normal for children); serum urea nitrogen, 12.4 milligrams per 100 cubic centimeters; total protein, 7.2 milligrams per 100 cubic centimeters; urine calcium, 77.4 milligrams in a total of 440 cubic centimeters of urine in twenty-four hours.

Aspiration biopsy was performed. On entering the bone there was profuse bleeding under pressure without pulsation. The blood clotted rapidly.

The pathological report of the biopsy specimen read as follows: "Benign cyst; possibly aneurysmal bone cyst, although this small fragment has the histological appearance of a benign giant-cell tumor. This pattern may be present in parts of aneurysmal bone cyst. It is assumed that there is no evidence of hyperparathyroidism."

FIG. 7

Roentgenogram made eight months after operation. Adjacent metatarsals are normal.

Because of the large size of the lesion with only the base of the bone preserved, and because of the possibility that it might yet prove to be a rapidly expanding giant-cell tumor, conceivably malignant, resection of the entire bone was decided upon. This was done on November 5, 1954, with the patient under intravenous suritol and nitrous oxide-oxygen anaesthesia. A blood-pressure tourniquet was used to maintain a bloodless field. A dorsal flap was used for exposure and the extensor tendon of the fourth toe was transected to facilitate exposure. Without the tourniquet, the exposed bone seemed to pulsate slightly, although this was not the consensus of the operating team. The cortical bone of the adjacent metatarsals was thin. The metatarsal was sharply dissected from its bed; the nutrient artery along the inferior surface of the shaft measured approximately one millimeter in diameter and it did not seem unusual. The tumor was entirely within the expanded cortical shell, and no part of the process was in contact with the soft tissues. The wound was closed with fine silk and dermalon, a drain being left in place in the bed of the bone. A firm pressure dressing and a light cast were applied to support the transverse arch.

The gross specimen, both before and after section, is shown in Figures 5-A and 5-B. It measured 7.1 centimeters in length and three centimeters in greatest diameter. The articular cartilage at both ends was normal. Almost the entire length of the bone presented a bulbous dilatation with a thin shell of cortex which crepitated. On dissection, the distal epiphysis could not be absolutely identified, but it did not appear to be involved. With the exception of less than one centimeter, the proximal segment of the diaphysis was the site of an irregular sac filled with blood clot, with irregular trabeculae of fibrous tissue interspersed with bone components traversing the walls of the saccules. The cortex in many areas was less than one millimeter thick but it was not penetrated at any point. Microscopic examination showed large vascular channels and numerous thick-walled vessels extending into smaller, dilated, and engorged capillaries. In some areas, the walls of these channels were composed of connective tissue rich with young fibroblasts. Numerous multinuclear giant-cells were seen in some areas, mainly within vascular walls. These giant cells were small and had comparatively small nuclei. These indications were considered characteristic of an aneurysmal bone cyst (Figs. 6-A and 6-B).

Crysticillin was administered postoperatively and, aside from slight marginal split-thickness necrosis

of the apex of the flap, healing was uncomplicated. The child was discharged on crutches on the eleventh postoperative day. Subsequently, development of correct carriage was coincidental with the re-establishment of adequate muscle capacity. The patient was given metatarsal-arch support and had no further difficulty in walking. She was enjoying full activity when last examined on June 14, 1955, seven months after the operation (Fig. 7).

In retrospect, we regret the omission of preliminary arteriographic study, or at least a study coincidental with surgery which might have been of unique value in observing the vascular background of the process. Shallow and Wagner used venography in the study of a pulsating giant-cell bone tumor in the popliteal area, without, however, any knowledge of value being gained from the study. In a disturbance of a distal segment of the circulation as presented in this case, a serial section technique of arteriography might prove to be of great value in showing the intraluminal vascular pattern which may be characteristic and diagnostic of this condition.

It may be questioned why conservative treatment was not employed. Because of the extent of the lesion, the possibility that pathological examination might reveal it to be a giant-cell tumor, and the danger of recurrence after curettement, the definitive procedure was decided upon. It was possible that the extremely rapid growth of the lesion during the seven months preceding surgery indicated an unusually active tumor, regardless of its benign appearance. Buschke and Cantril reported a similar lesion in a metacarpal bone which recurred rapidly after curettement and expanded, although roentgen therapy was applied. Eventually, amputation of the foot was necessary, despite the benign appearance of the lesion.

Roentgen therapy in the foot of so young a child would not have been considered even though the diagnosis had been that of a giant-cell tumor of benign proportions.

CONCLUSION

A recent experience with a proved aneurysmal bone cyst in a metatarsal bone seemed worthy of report since the lesion is so rare in the hands and feet, and, as Thompson had noted, its roentgenographic appearance in these areas is not as distinct as in other areas. A serial roentgenographic record of this lesion in its rapid development from an early phase, which is quite characteristic of a giant-cell tumor, has delineated the development of the entity through phases previously considered in its pathogenesis, and about which there has previously been confusion.

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Fracture about the Ankle Joint with Fixed Displacement of the Proximal Fragment of the Fibula behind the Tibia

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In January 1947, Bosworth reported a series of five cases of fractured ankle in which a situation existed that prevented adequate reduction. He called this "posterior fixation of the fibula behind the tibia". He pointed out that this situation is not recognized unless one is aware that it can occur and that reduction is possible only through open operation. The article clearly set forth the diagnostic criteria, the mechanism, and the pathology encountered. Recently, Fleming and Smith reported a similar case. However, they were able to reduce the fracture without operation. Soon after Bosworth's article appeared, the author was confronted with just such a situation and, fortunately, recognizing the type of fracture from Bosworth's description, it was possible to secure an adequate open reduction after closed methods had failed.

This paper is a report of two cases of fractures about the ankle joint with fixed displacement of the fibula behind the tibia (Figs. 1-A and 2-A). These fractures were treated by open reduction with excellent results (Fig. 1-B).

Unlike the cases in Bosworth's series, in one of our patients (Fig. 2-A) who had a trimalleolar fracture with displacement of the posterior marginal fragment, the proximal fibular fragment was not caught on the posterior ridge of the tibia but was fixed in the fracture site of the posterior lip of the tibia. The other patient (Fig. 1-A) had a compression fracture of the distal end of the tibia in addition to a fracture of the lateral malleolus. At operation in both of these patients, a strong instrument was inserted between the

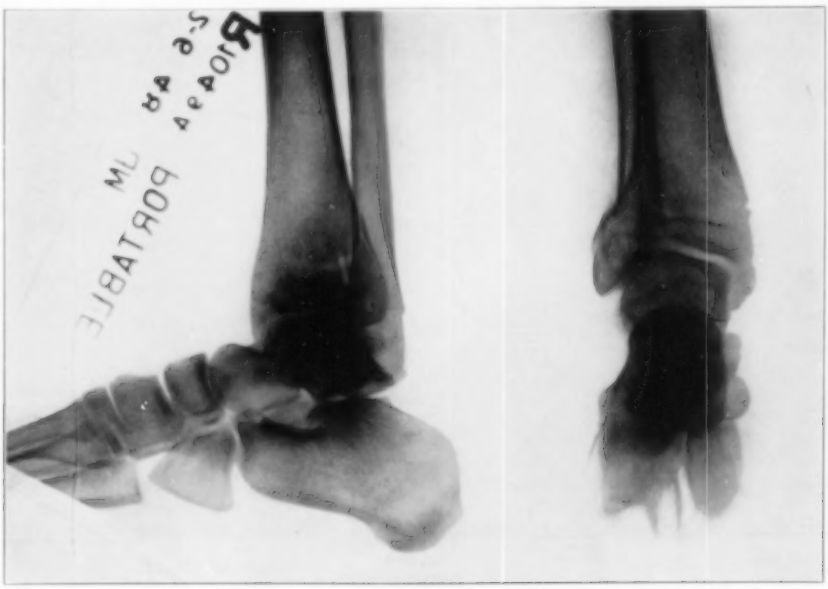

FIG. 1-A

Case 1. Anteroposterior and lateral roentgenograms. The position of the fibula seen on the lateral roentgenogram shows the type of fracture-dislocation present. Closed reduction was attempted without success.

FIG. 1-B

Anteroposterior and lateral roentgenograms nine months after open reduction. There is evidence of good healing. The patient was walking without difficulty and had a normal range of motion.

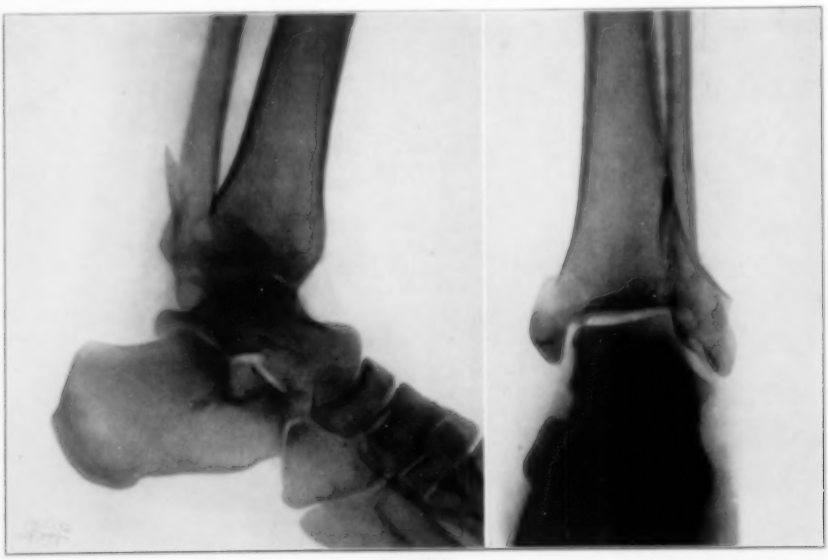

FIG. 2-A

Case 2: Anteroposterior and lateral roentgenograms demonstrating a trimalleolar fracture-dislocation with a fixed displacement of the fibula in the fracture site of the posterior lip of the distal end of the tibia.

FIG. 2-B

Anteroposterior and lateral roentgenograms of Case 2 showing the result one and one-half years after open reduction. This patient had a normal range of motion and had no symptoms.

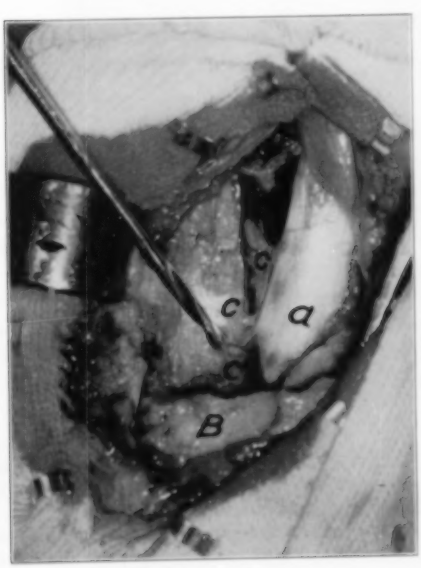

FIG. 3-A

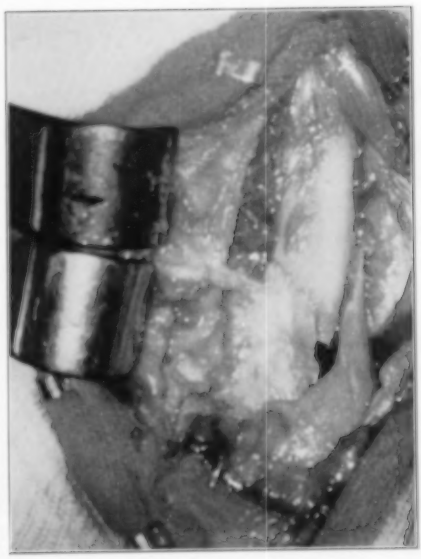

FIG. 3-B

Fig. 3-A: (A) Proximal fibular fragment can be seen fixed behind major tibial fragment.
(B) Distal fibular fragment.
(C) Posterior lip of the tibia fixed at fracture site. A small portion of the posterior lip is seen lying behind the proximal fibular fragment. The drill is pointing to the articular surface of the tibia at the inferior tibial-fibular articulation.
Fig. 3-B: Photograph showing the fibular fragments after reduction.

tibia and the proximal fibular fragment, and it was necessary to exert considerable force in prying the fibula loose. Reduction of the fracture was then possible without difficulty. In one of the patients (Fig. 1-B) a screw was used to stabilize the comminuted fracture of the distal portion of the tibia.

We are reporting these cases in order to emphasize the fact that this situation should be considered when fractures of the ankle involving the fibula are irreducible by closed methods. A lateral approach to the ankle will reveal the factors preventing the reduction and will give access to the mechanical deterrent. Figure 2-A shows the roentgenographic findings in this type of injury, and the condition is demonstrated in Figures 3-A and 3-B.

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Rupture of the Triceps Tendon *

BY KIRK J. ANDERSON, M.D., AND JOHN F. LeCOCQ, M.D., SEATTLE, WASHINGTON

From the Seattle Orthopaedic and Fracture Clinic, Seattle

Since a perusal of the literature has failed to disclose any reported cases of traumatic rupture of the triceps tendon, the report of two such ruptures may be of interest.

The tendon of the triceps brachii muscle consists of two aponeurotic laminae which join together above the elbow and are generally inserted into the posterior portion of the upper surface of the olecranon. A lateral band extends over the anconeus muscle to attach to the dorsal fascia of the forearm. The primary action of the triceps muscle is to extend the forearm, and the long head of the muscle may assist in adduction of the arm. The leverage of the muscle produces speed of movement at the expense of force.

Excessive strain placed against the resistance of the contracted triceps muscle results in the common olecranon fracture, rather than rupture of the triceps tendon. Attritional changes predisposing to rupture which are so common in the shoulder apparently do not occur in this tendon.

CASE REPORTS

Case 1. J. L., a man twenty-eight years old, was seen on September 3, 1952, two days after he had fallen from a log. The impact of the fall was received by the extended left forearm. On the following day he found that he could not hold the forearm above his head when raising his left arm.

Examination of the left elbow revealed prominent swelling and ecchymosis. There was complete inability to extend the elbow against gravity. A palpable defect proximal to the olecranon process was noted. Roentgenographic examination showed an intact olecranon process.

Surgical exposure revealed a complete rupture of the triceps tendon at the point of its insertion into the olecranon process. No bone substance was encountered in the tendon. Repair was accomplished by approximation of the triceps tendon to the olecranon by braided stainless-steel wire placed through two holes drilled in the olecranon.

* Read at the Thirtieth Annual Meeting of the North Pacific Orthopaedic Association, Portland, Oregon, May 18, 1956.

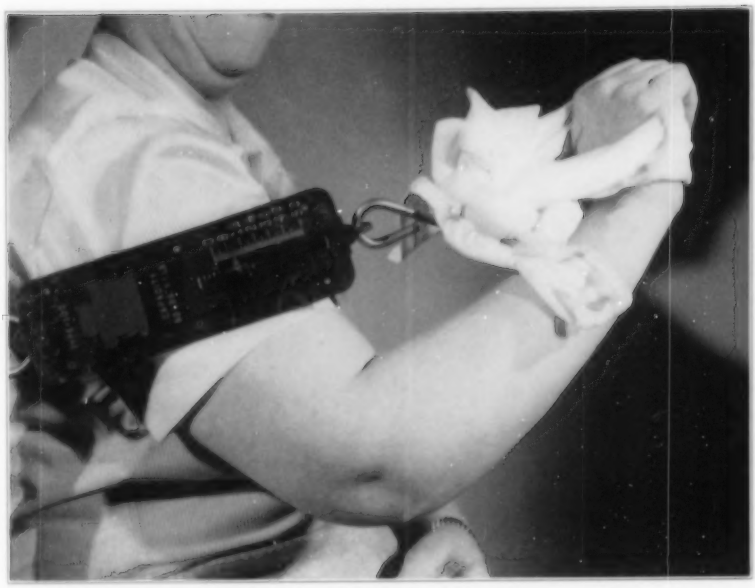

FIG. 1-A

Case 2. Resistive triceps power in the right elbow, measured preoperatively by spring tension balance, equals nine pounds.

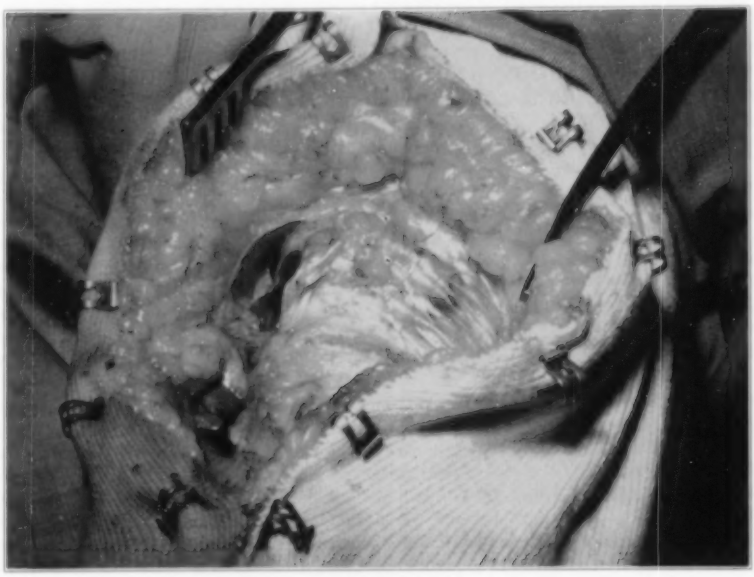

FIG. 1-B

Photograph of the right triceps tendon at operation. There is continuity of the tendon with a defect and thinning of the tendon proximal to the olecranon. Redundance of the tendon is evident when the elbow is completely extended.

During the postoperative period the arm was maintained in a posterior plaster splint for three weeks. Physical therapy was then started and was continued until full flexion of the elbow was obtained. Active extension was recovered with the exception of about 5 degrees, although complete passive extension could be accomplished. Strength in the left triceps muscle was comparable to that on the opposite side.

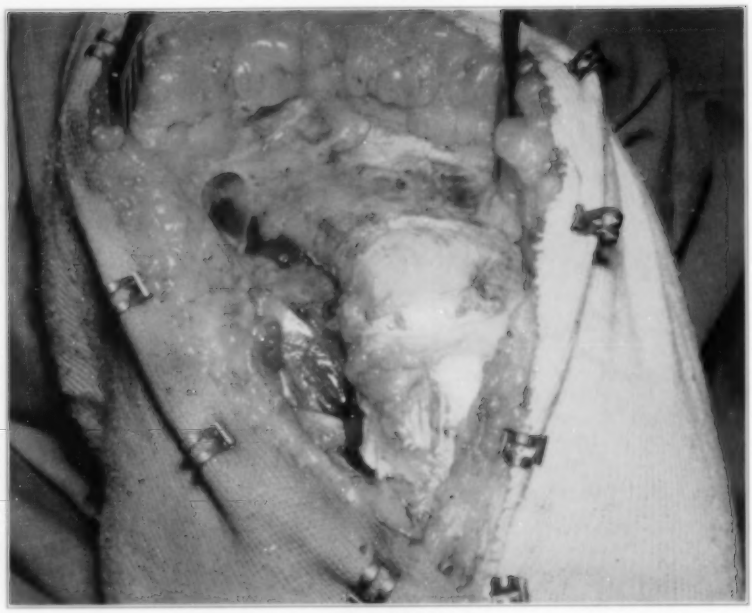

FIG. 1-C

Case 2. Photograph of same elbow demonstrating obliteration of redundancy of the tendon with the elbow flexed 90 degrees. An incision has been made in the periosteum of the olecranon for attachment of the plicated tendon.

CASE 2. A. L., a woman twenty-seven years old, was first seen on October 14, 1955. On October 17, 1954, she had struck the posterior aspect of the right elbow against the gearshift on her car during an automobile accident. Roentgenograms made at that time by her attending physician were negative for fracture. There was distinct swelling in the elbow which persisted for several weeks, and she could not extend the elbow beyond the 150-degree position for several months. Physical therapy improved the range of extension but she continued to have pain in the triceps tendon area, weakness when lifting particularly above the head, and ulnar neuritic symptoms.

Examination one year after the accident revealed full flexion of the right elbow but extension could not be accomplished through the last 10 degrees of range. Palpation produced a complaint of tenderness just proximal to the olecranon process and there appeared to be an interruption of the continuity of the triceps tendon at this point. Strength of the right triceps against resistance was approximately one-half that of the opposite triceps (Fig. 1-A). There was distinct tenderness over the ulnar nerve with accompanying hypo-aesthesia of the ulnar aspect of the hand and fingers. The clinical impression was that lengthening of the triceps tendon secondary to a partial intratendinous rupture existed, with an accompanying ulnar neuritis.

Surgery was performed on October 27, 1955. There was evidence of old hemorrhage in the triceps tendon. A palpable thinning and partial defect of the tendon proximal to the olecranon process was found. Complete extension of the elbow produced redundancy in the tendon; the tendon did not assume a normal appearance until the elbow was flexed 90 degrees (Figs. 1-B and 1-C). Repair was effected by preparing a periosteal flap over the olecranon process, to which the plicated, shortened triceps tendon was sutured by mattress-braided, stainless-steel suture material. It was necessary to shorten the triceps tendon two inches to obtain the desired tension of the tendon with the elbow completely extended. The ulnar nerve was found to be enclosed in a bed of adhesions and was, therefore, transplanted anteriorly.

The patient was promptly relieved of all pain and a normal range of motion was obtained eight weeks after surgery. Resistance exercises produced greater apparent strength in the injured muscle than in the uninjured left triceps, although it was recognized that the patient's right-handed dominance could well have been a factor in the result.

Proceedings

WESTERN ORTHOPEDIC ASSOCIATION

Prepared by the Editorial Committee of the Western Orthopedic Association: Keene O. Haldeman, M.D., *Chairman;* George L. Dixon, M.D.; Kirk J. Anderson, M.D.; and Robert Mazet, M.D.

The Twentieth Annual Meeting of the Western Orthopedic Association was held in Phoenix, Arizona, October 31 through November 3, 1956, under the Presidency of Dr. James Lytton-Smith. Summaries of the papers presented at this meeting follow:

Etiology of Spondylolisthesis. Dr. L. L. Wiltse [1] reported a study made in order to determine the incidence of spondylolisthesis in the families of twenty-four patients. The conclusion of this study had been that the incidence of a defective neural arch at the pars interarticularis was much higher in these families than it is in the general population.

In six cases, the defect in the pars interarticularis had been studied grossly and microscopically. No endochondral or intramembranous ossification had been noted, and there had been no evidence of periosteum over the end of the bone at the defect. There had also been no evidence of healing. One outstanding finding had been the presence of fibrillar fibrous connective tissue which was acellular and extended to the bony cortex of the defect.

Roentgenograms had been made of the members of the twenty-four families. Only direct forebears, siblings, and direct descendants had been included in the study, and the original patient had never been included since he represented a selected case. The incidence of the defect in these families was 31.3 per cent, as compared with an incidence of about 5 per cent in the general population.

It had not been possible to determine with certainty whether the trait is dominant or recessive, but the weight of evidence favored the view that it is recessive. At the time of writing a separate study was being made to determine this point. The presence of unilateral defects and variation in the amount of slipping indicate that the trait may assume different forms. It is not sex linked.

On the basis of these studies, the author had formulated the following etiological theory. The defect through the pars interarticularis is due to a congenital weakness or dysplasia. In patients with this defect lysis occurs because of the particular stresses which are exerted upon the involved segment of the spine. Occasionally, however, instead of complete lysis, healing takes place, which accounts for the elongated pars interarticularis in some cases and which may account for the presence of a unilateral defect. Due to the peculiar construction of this area, repair by means of callus formation does not occur as it does in other parts of the body. It seems apparent that there must be a congenital element; otherwise this fracture would not occur as a result of simple stresses, and when it did occur as a result of severe trauma, it would heal. The exact nature of this congenital weakness remains an enigma.

The Coracoclavicular Joint. An Anatomical, Pathological, and Surgical Study. Dr. John W. Cooper [2] reported that this anomalous joint has been found by other investigators in routine anatomical studies and that it has been reported to be a regular finding in the gorilla and gibbon monkey, animals in which the shoulder is located high above the suprasternal notch. In his own studies he had found it to be a common condition in some species of gibbon monkey and a frequent condition in the orangutan. In the gorilla, however, it was apparently an uncommon condition, for in the eight gorilla skeletons examined there had been no evidence of this anomaly.

Four hundred and forty-five specimens of the human clavicle had been examined in order to determine the degree of projection of the conoid and trapezoid tubercles from the flat surfaces of the bone. In one group of 217 clavicles the findings had been as follows: in 155 specimens the posterior borders were perfectly round, in twenty-six specimens there were slight to marked projections which extended 30 degrees backward and downward, and in twenty-five specimens the conoid tubercles had marked inferior projections, the mass of the tubercles being at a posterior angle of 10 degrees or less. In the other group of 228 specimens measurements had been made to determine the height of the conoid tubercles. These measurements had revealed that there was a variation in height of from 1.5 millimeters to nine millimeters and that seventeen of the 228 specimens were markedly enlarged, that is, were from five to nine millimeters in height. It was in this small group of specimens with enlarged tubercles that all the anomalous joints (four bilateral cases and two unilateral cases) had been found. Excessive height of the trapezoid tubercle had been found in only one specimen; nevertheless, it was felt that a trapezoid-coracoid articulation was a possibility. One case of this anomaly, due to trauma, had been found in this study.

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[2] 353 Young Hotel Building, Honolulu 13, Hawaii.

The author reported that in his practice he had seen two patients with bilateral deformities during the previous two years. One of these patients had been operated upon, making the fourth patient with this deformity to be so treated. The case history of this patient was as follows. A nineteen-year-old Chinese boy had been bumped in a volleyball game while his arm was extended over his head, and as a result had sustained an injury of the left shoulder. Immediate pain had been noted. Conservative treatment had been carried out over an eighteen-month period, but no improvement had been obtained. Although examination had revealed no limitation of motion, extension of the left arm above the head produced muscle spasm with pain in the coracoid region. Roentgenograms had revealed bilateral coracoclavicular joints. Surgical removal of the entire left joint, including the clavicular and the coracoid facets, had been done with difficulty through the anterior half of a sabre-cut incision. During this procedure, a distinct joint capsule and cartilage-covered but eroded facets had been found. It was felt that the conoid ligament had been destroyed as a result of the surgical excision, and postoperatively the clavicle had appeared to be more prominent at the acromioclavicular joint than before. Both sides of the joint were removed purposely, not only to make study of the specimen possible, but also to obtain surgically two new surfaces so that fibrous repair would bridge the gap and provide a new ligamentous support. Six months after the operation, all discomfort in the region of the surgery had disappeared, and twenty months after the operation, the patient was taking special Judo wrestling classes in the United States Air Force.

The author concluded that the coracoclavicular joint occurs in human beings quite frequently, its incidence being one in every thirty-eight to forty-five individuals. Enlargement of the conoid tubercle is usually responsible for the formation of this joint, although in rare cases enlargement of the trapezoid tubercle is the cause. Since the conoid tubercle is on the posterior-inferior surface of the clavicle, it would appear that a posterior surgical approach would cause the least trauma. With age and use, the coracoclavicular joint is subject to the same degenerating processes as other joints are and may require surgery.

Mobility Studies of the Lower Portion of the Lumbar Spine in Relation to Low-Back Pain. A Preliminary Report. Dr. Merrill C. Mensor [3], Dr. Alvin J. Gross [4], and Dr. Gene Duval [5] stated that in the absence of precise diagnostic information, many spine fusions have been performed under the "catch-all" diagnosis of unstable back. The authors had made a study of one aspect of this problem: the relative importance of the absence of motion (as determined roentgenographically) at the fourth lumbar and the lumbosacral levels in patients suffering from low-back conditions due to various causes.

Two hundred and thirty-two consecutive patients seen in the authors' private practices had been examined clinically and roentgenographically. Beside the routine views (anteroposterior, lateral, oblique, spot lateral, and up-shot in the lumbosacral plane), lateral flexion and extension roentgenograms had been made with the patient in the upright position. The patient had been securely immobilized against the upright table by means of a radiolucent sling and the tube had been centered at the level of the third lumbar intervertebral disc space. Evaluation of the presence or absence of motion at the lumbosacral junction had been determined by superimposing the various roentgenographic views of the sacrum. The views of the fifth lumbar body had then been superimposed, and the amount of motion between the fourth and fifth vertebrae ascertained. The age of the patients ranged from seventeen years to seventy years. Sixty-three per cent had chronic symptoms and 37 per cent had acute symptoms, the arbitrary dividing line between chronic and acute being two months. The final clinical classification of the conditions analyzed was as follows: sprain in twenty-five cases (11 per cent); sprain with degenerative changes including discogenic disease in 100 cases (43 per cent); lumbar-intervertebral-disc disease in fifty-one cases (22 per cent); congenital anomaly in twenty-seven cases (12 per cent); and miscellaneous conditions in twenty-nine cases (13 per cent).

Of the 232 patients examined, 122 showed absence of motion at the level of one or both of the two lower lumbar vertebrae. This limitation of motion was most pronounced in those with chronic conditions and in those who were in the fourth, fifth, or sixth decade of life. Limitation had been found in 88 per cent of the patients with sprains, in 73 per cent of those with sprains associated with antecedent degenerative processes, and in 100 per cent of those with intervertebral-disc syndrome. In the group with congenital anomalies, it had been found in only 50 per cent, however; and in the group with miscellaneous conditions, it had been found in only 38 per cent.

The authors concluded that absence of motion may be found roentgenographically in a high proportion of patients with low-back disabilities and stated that this condition is the secondary result of muscle spasm followed by changes in the peri-osseous tissues. In spines which are the site of traumatic disease or anomalous change, this loss of motion serves as a protective mechanism.

Congenital Dislocation of the Hip among the Fort Apache Indians. Dr. Bertram S. Kraus [6] and Dr. John R. Schwartzmann [7] had made an anthropological study of a so-called primitive population,

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[6] Department of Anthropology, University of Arizona, Tucson, Arizona.
[7] 2415 East Adams Street, Tucson, Arizona.

the Fort Apache Indians. This study was designed to evaluate reports of the high incidence of congenital dislocation of the hip.

In order to interpret the available medical data and to determine the influence of hereditary factors, an understanding of the social structure of this population was necessary. It was noted that, biologically, there were three distinct populations on the Fort Apache Reservation. These three populations represented the three independent bands which had migrated to this area from western Canada 500 to 600 years ago. Adopting certain farming habits of the Pueblos, these three bands had settled down and increased in number. From the first they were endogamous, that is, band members married only other band members, with the result that, although close relatives were avoided as marriage partners, all members of each band became interrelated, albeit four, five, or ten times removed. The bands are still endogamous today.

Over 700 Apaches were selected at random from the reservation to be given blood tests. An analysis of the blood specimens showed that only two types of blood, *O* and *A*, were present. The incidence of type *O* was found to be 72 per cent in two of the bands and 61 per cent in the other band, a finding that indicated a statistically significant difference in the gene-frequency patterns of the three different bands. An analysis of the Rh factor revealed a similar differentiation. This information was considered vital to a fuller understanding of the distribution and incidence of congenital dislocation of the hip among these Indians.

An effort had been made to determine the incidence of congenital dislocation of the hip by means of clinical and roentgenographic examinations. Among the adults, children, and infants studied, 107 cases had been found. This represented a minimum incidence of 3.05 per cent for the total estimated population of 3,500. A thorough study of the entire population had not been possible, however, and the authors estimated that the cases found were probably not more than 50 per cent of the total number of cases. Cases of dysplasia and subluxation had not been included. Of the 107 Indians found to have congenital hip dislocation, twenty-one were males and eighty-six were females, a sex ratio of one to four. The incidence of bilateral dislocation was 48 per cent.

The authors concluded that heredity is a major factor in congenital dislocation of the hip. They said that this condition is not inherited as a simple recessive Mendelian trait and that it may or may not skip a generation. The various phenotypic manifestations of the involved gene or genes are not understood.

The incidence of congenital dislocation of the hip in this aboriginal American Indian population is believed to be the highest on record in the world.

Epiphyseal Arrest with Staples. Follow-Up of Fifty-Two Cases. Dr. Jack Moshein [8] presented an evaluation of the results obtained in a consecutive series of fifty-two patients treated by surgical arrest of the distal femoral and proximal tibial epiphyses. Metal staples had been used, and the operations had been performed between 1949 and 1953. In forty-nine of the patients, both the lower femoral and upper tibial epiphyses had been stapled. In one patient only the femoral epiphysis had been stapled, and in two patients only the tibial epiphysis had been stapled. The youngest patient was six years, nine months old and had one and one-half inches of shortening, while the oldest patient was fifteen years, nine months old and had two and one-half inches of shortening. The conditions for which the operations had been done were: poliomyelitis, thirty-five cases; tuberculosis of the hip, six cases; congenital shortening, five cases; Legg-Perthes disease, two cases; osteomyelitis of the hip, two cases; club-foot, one case; and congenital dislocation of the hip, one case.

The average discrepancy in the group with poliomyelitis had been one and three-quarters inches and the average age at the time of operation had been ten years, five months. Following the operation, at an average age of twelve and one-half years, the average discrepancy had been five-eighths of an inch. Thus, five-eighths of an inch of shortening had been obtained each year, a result which compares favorably with that of surgical epiphyseodesis. In nine children, the staples had been removed after equalization of the extremities had been obtained. Further study of five of these children had revealed that the epiphyses had resumed growth following removal of the staples; in fact, in one child both extremities had grown two and one-eighth inches in the next two years. In no patient had a varus or valgus deformity been produced.

The results in the six patients with tuberculosis were poor. At the time the staples were inserted, the average shortening was three and five-eighths inches and the average age was eleven and one-half years. At the time of follow-up, when the average age was thirteen years, nine months, there remained an average discrepancy of three and one-quarter inches.

In five cases of congenital shortening of the lower extremity, the stapling had been done before the patient was eleven, the average age being nine years, ten months. The average shortening was two inches before the operation and three-quarters of an inch following the operation.

The two patients with Legg-Perthes disease had discrepancies of one inch. In one of these patients there was complete equalization of the limbs two years later, but the other patient still had a discrepancy of three-quarters of an inch at the time of writing. In one of the two patients with osteomyelitis of the hip, there was a shortening of three and one-eighth inches before the operation, when the patient was eleven.

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Two years later, only three-quarters of an inch of shortening remained. In the other patient with osteomyelitis, the shortening was one and one-eighth inches before the operation, when the patient was eleven years, nine months. Following removal of the staples sixteen months later, the limbs remained equal in length. The patient with congenital club-foot had two inches of shortening at twelve years of age. Two years later, one and one-half inches of overgrowth on the unstapled side had occurred. The staples had been removed, but the discrepancy had persisted. The patient with untreated congenital dislocation of the hip had one and one-half inches of shortening. At the time of follow-up there had still been one inch of shortening and the epiphyses had closed.

The complications in this series had included temporary peroneal-nerve paresis in one patient and joint effusion in two patients. In three patients full knee flexion had not been regained until after more than the usual three weeks, and in four patients it had been necessary to reinsert the staples.

Arthroplasties of the Hip. Dr. C. B. Larson [9] pointed out that use of the lateral and posterior approaches to the hip has permitted modification of the surgical techniques used in arthroplasty. The more complete view obtained by these approaches allows the surgeon to vary his technique as it seems necessary and to transplant either the tendon of the glutaeus medius or the entire trochanter as he desires.

Dr. Larson also emphasized, however, that there are definite limitations to what can be obtained by surgery, these limitations being imposed by (1) the surgeon's inability to control the habits and motivation of the patient, (2) his inability to control fibroblastic development, and (3) his inability to control bone proliferation or overgrowth.

Evaluation of Fifty-Five Prosthetic Arthroplasties of the Hip from the Seattle Orthopaedic and Fracture Clinic. Dr. H. H. Nash [10], Dr. John F. LeCocq [11], Dr. E. A. LeCocq [12], Dr. D. G. Leavitt [13], Dr. H. E. Emmel [14], Dr. K. J. Anderson [15], and Dr. J. Garth Mooney [16] reported a series in which fifty-five hip prostheses had been inserted in fifty-three patients by eight surgeons. Forty-six of the patients were women. The youngest patient was thirteen, the oldest was ninety-two, and eighteen were in the eighth decade of life. In forty of the fifty-three patients the prosthesis had been implanted at least eighteen months prior to the time of writing, and in three it had been implanted over five years prior to the time of writing.

Twenty-seven of the operations were performed for old (six months or more) fractures or dislocations; eleven were performed as the primary treatment for femoral-neck fractures; and five were performed as the secondary treatment for recent femoral-neck fractures, primary treatment having failed. Other conditions treated were: rheumatoid arthritis, five cases; degenerative arthritis secondary to congenital hip dysplasia, three cases; and malum coxae senilis, three cases. In seven cases the operation had been done following failure of previous arthroplasty (in three of the previous operations, nylon prostheses had been used; in two, Vitallium cups had been used; and in two, fascial arthroplasty had been done).

In almost every patient the lateral approach had been used, and in most patients detachment of the greater trochanter had been done. In a few of the patients in whom arthroplasty had been used as the primary treatment for fresh fractures, an anterior approach had been used. Oxycel gauze had been used in half of the patients in order to minimize new-bone formation.

Forty of the results had been classified as *satisfactory*, eight as *unsatisfactory*, and seven as *failures*. The complications encountered included fracture of the femoral shaft, two cases; dislocation of the prosthetic head, two cases; peroneal palsy as a result of postoperative splinting, two cases (full recovery was obtained in both cases); infection of the hip joint, two cases; persistent adduction contracture, one case; and hematocele formation in the region of the adductor tenotomy, one case. One patient had died following the operation as a result of fat embolism and bronchopneumonia. In the fourteen patients operated upon in the year prior to the time of writing, there had been no complications.

A more careful follow-up study had been made of the forty patients who had been operated on at least eighteen months prior to the time of writing. In 63 per cent of these patients the results were considered satisfactory. Of the various types of prostheses used, the Eicher type was considered to have produced a definitely higher percentage of good anatomical results, relief from pain, and fair or good functional results.

The surgeons who performed these operations believed that their surgical technique had become sufficiently proficient so that in the future postoperative complications would be minimal. They felt that prosthetic replacement is often indicated to treat femoral-neck fractures in the elderly patient and emphasized that the age and general condition of the patient should be taken into considerstion in the evaluation of the end result. Of the prostheses used, the intramedullary-stem type seemed the best. The results reported

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[14] 1011 Summit Avenue, Seattle 4, Washington.
[15] 1011 Summit Avenue, Seattle 4, Washington.
[16] 1011 Summit Avenue, Seattle 4, Washington.

in this series of patients treated at the Seattle Orthopaedic and Fracture Clinic are more encouraging than those reported by many other groups.

End-Result Study of Vitallium-Cup Arthroplasties of the Hip from the Seattle Orthopaedic and Fracture Clinic. Dr. Harry E. Emmel [14], Dr. John F. LeCocq [11], Dr. E. A. LeCocq [12], Dr. D. G. Leavitt [13], Dr. H. L. Leavitt [17], Dr. Kirk J. Anderson [15], Dr. Henry H. Nash [10], and Dr. J. Garth Mooney [16] reported that the same group of surgeons who had performed the arthroplasties described in the previous paper had also performed a series of operations in which ninety-four Vitallium cups had been inserted in eighty-six patients. The age range in this series had been from sixteen years to seventy-two years, and fifty-six of the patients had been males.

In the total series, ninety-three patients had been operated upon for the following conditions: septic arthritis, eight cases; congenital dislocation, nine cases (four bilateral); slipped femoral epiphysis, six cases (three bilateral); Legg-Perthes disease, two cases; rheumatoid arthritis, eight cases (six bilateral); fracture dislocation, four cases; aseptic necrosis, two cases; osteo-arthritis, fifty-three cases; and arthrokatadysis, one case. Of these ninety-three patients, eighty-six had been followed up.

Prior to 1950, the classic method of Smith-Petersen had been used. After 1950, however, the following modifications had been introduced: the use of the posterolateral approach, the transplantation downward of the greater trochanter; the removal of less bone from the femur and acetabulum; the performance of complete capsulotomy and synovectomy; and the use of oxidized cellulose gauze in order to minimize new-bone formation.

The postoperative complications had included: dislocation, two cases; massive new-bone formation, four cases; infection requiring drainage, four cases; temporary peroneal palsy, three cases; thrombophlebitis, two cases; pulmonary emboli, three cases; and absorption of the femoral head and neck, two cases. In eight patients the cup had been removed; also in eight patients secondary obturator or sciatic neurectomy had been done; and in one patient the lateral cutaneous nerve of the thigh had been sectioned.

The results had been classified as follows: excellent in six patients (7.0 per cent); good in thirty-four patients (39.5 per cent); fair in thirty-one patients (36.0 per cent); poor in seven patients (8.1 per cent); and failure in eight patients (9.3 per cent).

Hip-Socket Arthroplasty. The Principles and Surgical Technique of a Method of Treatment of Malum Coxae Senilis. Dr. M. R. Urist [18] stated that the two types of hip-joint arthroplasty most commonly used are (1) covering of the femoral head by a membrane or a cup of some type and (2) replacement of the femoral head and part of the neck by a prosthesis. He then described a third type of arthroplasty which consists in resurfacing of the acetabulum by means of a Vitallium socket fixed to the pelvis. In this operation, if it is correctly done, the acetabular fossa is preserved, the depth of the acetabulum is the same after the operation as before, the stability of the joint is maintained by muscle balance, and only eburnated bone is removed from the femoral head. The main principle of this operation is that as much of the femoral neck as possible is preserved as a lever arm.

The essential steps in the operation are as follows. Exposure is obtained through a posterolateral incision. The glutaeus maximus is then split, the cut paralleling the line between the posterior-superior spine of the ilium and the greater trochanter of the femur. Following this, the glutaeus medius, piriformis, rectus femoris, iliacus, glutaeus minimus, and external rotators are detached at their insertions, and the joint capsule is removed from the acetabular rim. The femoral head is dislocated, and all diseased or eburnated bone is reamed out, leaving a bleeding surface of cancellous bone. The acetabulum is then shaped with special (coaxial) reamers, and a locating or trial socket is introduced in order to determine the proper size, position, and alignment of the metal socket. When a satisfactory position has been determined, a trident broach is inserted through three holes in the locating socket in order to make holes in the acetabular cortex for the shoe nails which will hold the final socket in place. The holes having been made, the metal socket is introduced and gently tapped into place. The hip is then reduced, and the wound closed in layers.

Following the operation a special abduction splint is used for two to three weeks. This splint holds the limb in wide abduction and internal rotation, a position which allows the patient to sit up or lie flat. Graduated exercises are prescribed, and after six weeks, ambulation on crutches with little weight-bearing is begun. Full weight-bearing is not allowed until after at least six months.

Fifty-two hip-socket arthroplasties had been performed; twelve cases with over three-year results were analyzed prior to the time of writing. In 80 per cent of the patients with malum coxae senilis, good results had been obtained. Treatment by this method is not recommended for any other condition.

Bone Tumors in Children. Dr. John J. Toma [19] reported that of 4,754 children admitted to the Children's Hospital School in Baltimore, seventy-four had had primary bone lesions. In sixty of these chil-

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[19] 133 South Lasky Drive, Beverly Hills, California.

dren the lesions had been benign, and in fourteen they had been malignant.

Résumés of twelve of the fourteen cases of malignant tumors were given. In each of these cases the diagnosis had been established by means of biopsy, examination of the amputated specimen, and autopsy. In five of the cases, the pre-biopsy diagnosis had been incorrect—osteomyelitis (two cases), sprain, bursitis, and Legg Perthes disease. In half of the twelve cases, a history of trauma to the involved area had been given.

The most constant symptom was pain. The presence of this symptom should alert the physician to the possibility of malignant growth. Elevation of the serum alkaline phosphatase, hypercalcaemia, and hypercalciuria were also frequently found.

Roentgenograms may show areas of either bone destruction or bone formation, depending on the type and age of the tumors. None of the changes shown by the roentgenograms may be considered pathognomonic, however, and the diagnosis can be established only by biopsy. Extirpation remains the most certain form of treatment.

Dr. J. Vernon Luck [20], in his review of this paper, stated that it is extremely difficult to be certain of the diagnosis of bone tumors in children. The rapid changes in the concepts concerning these tumors and the variety in the reactions which occur in children's bones make the roentgenograms and microscopic slides very hard to interpret. Frozen sections of sarcomata may be particularly misleading.

Fibrosarcoma Following Single Trauma. Dr. Stanley S. Tanz [21] reported a case in which a malignant growth had appeared on the patient's hand some months after injury.

A young man, twenty-four years old, had struck the back of his hand against a guardrail while loosening a nut wrench. The blow had fallen on the area between the first and second metacarpals, and following the trauma numbness in the region of the median nerve had developed. Injury to this nerve had been the diagnosis two weeks later. There had been no sensory or motor loss, however, and the patient had disappeared without further treatment. A year later, the patient had returned, complaining of a "pinching, burning sensation" in the median-nerve region. At this time there had been tenderness over the proximal portion of the proximal palmar crease as well as weakness of grip and decrease of pain reaction to pinprick. A painless nodule near the center of the proximal flexion crease had been revealed by palpation but could not be found at exploration.

Twenty months after the trauma, operation had been done and a mass, one and one-half inches in diameter, had been excised from beneath the scar caused by the previous exploration. This mass had been beneath the palmar fascia, overlying the adductor pollicis and the first lumbricalis. The pathological diagnosis had been fibrosarcoma, and amputation through the mid-arm had been performed. Ten months after the operation there had been no evidence of metastasis.

Aneurysmal Bone Cyst. A Method of Treatment. Excisional Biopsy with Tibial-Bone Graft. Dr. Walter Feinstein [22] and Dr. F. W. Ilfeld [23] reported the case of a sixteen-year-old boy with an expanding lesion which had involved the entire first metacarpal of the left hand. The findings of the blood chemistry studies had been normal. At operation, the entire metacarpal had been excised and a cortical tibial graft had been inserted. This graft had been placed in slots made in the greater multangular and the proximal phalanx. Following the operation, the hand had been immobilized in a plaster cast for five months. Nine years later the graft had assumed the shape of the missing metacarpal and had a definite cortex and medulla. The cosmetic and functional result had been excellent.

At the time of the operation the pathological diagnosis had been giant-cell tumor. At the time of writing, however, it was thought that the true diagnosis was aneurysmal bone cyst.

Bilateral Benign Cystic Disease of the Carpal Scaphoid. Dr. H. B. Grover [24] stated that the differential diagnosis of bone lesions is difficult and that, roentgenographically, many of these lesions have a cyst-like appearance. Factors which are helpful in making the diagnosis include the bone in which the lesion is found, its location within this bone, its symmetry or lack of symmetry, the presence of thinning or expansion of the cortex, the periosteal-reaction patterns, the age of the patient, the findings of blood chemistry studies, the nature and intensity of the pain, and the presence of swelling and of elevation in temperature.

Dr. Grover reported a case in which benign cysts of an unusual type had been found in both carpal naviculars.

A forty-year-old restaurant manager had been seen because of pain in the right wrist of several months' duration. There had been no history of trauma. Roentgenograms had revealed a cystic lesion in the navicular; this lesion had broken the cortex in two places and had almost completely destroyed the bone. The findings of blood chemistry studies had been normal. Following a tentative diagnosis of central chondroma

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[24] 327 Georgia Street, Vallejo, California.

or benign simple cyst, it had been felt that excision of the entire lesion would be more effective than curettement and this had been done. Six weeks after the operation, pain had developed in the opposite wrist and roentgenograms had showed a cystic lesion of the navicular of the left hand, without erosion or breaking-through of the cortex. A year after the excision of the navicular of the right hand, the other navicular had also been excised, because of increased disability. Study of the microscopic sections had revealed that the lesion was a benign cyst. Vitallium replacements had been inserted in both wrists, and ten months after the second operation, the patient had had excellent function and had been able to play golf without difficulty.

The Diagnosis and Treatment of Certain Traumatic and Degenerative Conditions of the Knee Joint. DR. KEENE O. HALDEMAN [25] discussed several common derangements of the knee. He pointed out that the articular cartilages are subjected to constantly repeated trauma during walking, and that injuries and degenerative changes due to acute trauma or to wear and tear are frequent. He emphasized the absence of blood supply in the cartilages and the inability of this tissue to repair itself.

Tears of the meniscus: The author stated that, except for peripheral tears without complete displacement, prompt operative treatment is indicated. In a bucket-handle tear only the displaced portion should be removed, but in other types of tear, the anterior three-fourths of the cartilage should be removed. Hypermobile cartilages should be entirely excised.

Cysts of the meniscus: These cysts are a degenerative phenomenon and therefore gradually increase in size; for this reason the involved meniscus should be excised.

Osteochondritis dissecans: In the treatment of this condition the author removes the loose fragment, excises any degenerated bone which is present, and drills several holes in the subchondral bone.

Chondromalacia: The author stated that the appropriate method of treatment depends upon the degree of involvement of the cartilaginous surface. In superficial lesions, the fibrillated and softened cartilage should be excised. In lesions in which subchondral bone is exposed over less than half of the surface of the patella, the degenerated cartilage should be removed and multiple holes should be drilled through the subchondral bone. In advanced lesions, the entire patella itself should be removed.

Osteochondromatosis: In the treatment of this condition, the author removes the joint mice and, if loose-body formation is still present, performs synovectomy.

For all these lesions the author emphasized the importance of early diagnosis and prompt surgical treatment.

The Results of Combined Drug Therapy Plus Early Fusion in Bone Tuberculosis. DR. A. W. STEVENSON [26], DR. A. R. ALLEN [27], and DR. CORRINE FARREL [28] reported the results obtained by combined drug therapy and surgery at the Central Washington Tuberculosis Hospital since June 1952. All the patients admitted to this Hospital since that time had received streptomycin, para-aminosalicylic acid, and isonicotinic acid hydrazid both before the operation and during the six months after the operation.

Eleven patients had been treated by spine fusion, three by knee fusion, one by hip fusion, and one by saucerization of the fibula. The average age of these patients was twenty-six years, and the average length of hospitalization was 237 days, including seventy-two days of preoperative care. Thirteen of the patients had had tuberculosis of some other organ or system, and five had had sinus tracts. The majority of the sinuses had closed following combined drug therapy, and those which had not closed had been excised at the time of fusion.

There had been no deaths, and no pseudarthroses had developed. All the sinuses had remained closed, and there had been no further dissemination of the disease in any patient. All the patients had returned to their former occupations.

In the cases in which the lesions were in the hip, knee, and fibula, the diagnosis had been established by biopsy. In the seven cases in which the lesions were in the spine, positive culture of material from lesions located elsewhere in the body had been obtained. In the remaining four cases characteristic roentgenographic findings had been observed, and the results of the Mantoux test had been positive.

In five small children with tuberculosis of the spine, bank bone had been used to obtain fusion. This bone consisted of ribs taken from patients with pulmonary tuberculosis.

The authors advocated that fusion be performed as soon as the patient's general condition is favorable following admission to the hospital. They stated that fusion may be done in the presence of a draining sinus, but that the sinus should be resected at the time of fusion. In this series they had not voluntarily entered any abscesses.

In his discussion of this paper, DR. L. M. OVERTON [29] agreed with the authors that combined drug therapy alone cannot be relied upon to heal bone lesions and that fusion is still necessary.

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[26] 7 South Tenth Avenue, Yakima, Washington.
[27] Selah, Washington.
[28] Omaha, Nebraska.
[29] 4800 Gibson Avenue, Albuquerque, New Mexico.

Bone Lesions in Disseminated Coccidioidomycosis. Dr. J. W. Cortner [30] and Dr. John R. Schwartzmann [7] presented a report on the nature, incidence, and treatment of coccidioidomycosis.

This condition is a fungus infection which is caused by the inhalation of the spores of *Coccidioides immitis*. In the geographical areas in which this fungus is endemic, the primary, or pulmonary, infection is quite common and is not fatal. Secondary dissemination occurs in one of every 500 Negroes and in one of every 1000 whites and has a much more serious prognosis. In about 20 per cent of these patients skeletal lesions develop. The diagnosis is established either by identification of the organisms or by precipitation and complement-fixation tests. The tissue reaction caused by this disease, as demonstrated by microscopic study, is identical with that caused by tuberculosis.

The authors reported their findings in a series of twenty-two patients with forty bone lesions proved to be coccidioidomycosis.

The first change which had been apparent roentgenographically was demineralization. This had been followed by the appearance of cystic areas and in one patient, during the late stage, a periosteal reaction had been found. The laboratory data had revealed definite progressive changes, including eosinophilia, albuminuria, and elevation of the sedimentation rate, the latter often being out of proportion to the patient's apparent illness. All the patients with an eosinophil count of above five had died. The presence of a high fever was considered a poor prognostic sign. No specific drug therapy is known, and treatment is general. In patients with bone lesions, surgical incision and drainage, followed by plaster-cast immobilization, is the usual procedure. If the disease is limited to one extremity, amputation may sometimes be done. The mortality rate is much higher in the dark-skinned races.

Four Unusual Cases of Osteomyelitis in Adults. Dr. L. N. Cozen [31] reported the cases of four patients with unusual types of osteomyelitis. In two of these patients, abscesses had developed in the vicinity of closed fractures, and in two, abscesses had developed adjacent to rheumatoid joints.

In the first case a fifty-year-old woman had sustained a closed fracture of the tibia and fibula. Treatment had included skeletal traction for six weeks, followed by plaster immobilization. Union had been delayed, and five and one-half months after the injury, it had been decided that bone-grafting should be done. Following the making of the incision, however, an abscess containing Staphylococci had been found superficial to the periosteum. The bone-grafting operation had, therefore, not been performed. No sinus had developed.

A sixty-year-old man had tripped and fallen on his right side. He had been bedridden, and his right hip had become swollen and red. When the wound had begun to drain, he had entered the hospital. Roentgenograms had revealed an ununited fracture of the femoral neck. Five and one-half months after the injury, the head fragment had been removed because of persistent drainage. The organism grown on culture was Pseudomonas.

In the third case reported by the authors, the patient was a thirty-eight-year-old man who had had rheumatoid arthritis for eight years. In this patient a lump had developed in the left sternoclavicular area. At operation it had been found that this lump was caused by enlargement of the proximal end of the clavicle, and this portion of the bone had been removed. Within the fragment a small abscess had been found, but no organism had been identified.

A woman, thirty-one years old, had twisted her left knee. During the next four months her knee had remained moderately swollen and painful. Three weekly injections of hydrocortisone acetate had provided little relief, and biopsy had revealed hyperaemia of the synovial membrane and irregularity of the lateral femoral condyle with softening of the bone beneath. Microscopic examination had revealed osteomyelitis, but no organism had been recovered.

Xiphodynia. Dr. H. E. Crowe [32] presented a report of a case of xiphodynia.

A husky electrician had suffered gastric pain for two years. He had been on an ulcer diet during this period and had twice received thorough examinations, for suspected coronary and gall-bladder disease. Two gastro-intestinal series had been done, extensive blood chemistry studies had been carried out, and esophagoscopy and gastroscopy had been performed. The results of all these procedures had been negative. Cardiac surgery for cardiospasm had been urged, but the patient had refused. Two years after its onset, the pain had become so severe that the patient had been confined to bed and even then was comfortable only in a flexed position. On examination it had appeared that constant acute tenderness of the xiphoid was the most prominent finding and that the tension produced in this region by any attempt to assume an erect posture caused pain.

The similarity between this condition and coccygodynia was obvious, and excision of the xiphoid had been advised. At operation the xiphoid had been found to be displaced upward behind the distal end of the sternum for one-half an inch, a position which suggested a posterior-superior dislocation. Later, after his

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recovery, the patient recalled that at one time he had held a piece of electrical apparatus between his chest and the bench while working on it with both hands and that following this, he had been aware of some soreness in the chest. It was about this time that his abdominal discomfort had begun.

In the open discussion of this report, another case of xiphodynia was cited. In this case excision had not provided relief, and the cause of the pain had ultimately been discovered to be an abdominal aneurysm.

Cervical Strain with Residual Occipital Neuritis. Dr. Ralph Pietrobona [33], Dr. Warren B. Allen [34], and Dr. Harry R. Walker [35] presented a review of the anatomy and causes of cervical strain. This report was made with particular reference to occipital neuritis, which had developed in 53 per cent of the authors' patients despite conservative treatment. Of the 410 patients with occipital neuritis, 337 had been followed completely. In addition to the usual conservative measures, these patients had been treated by single or multiple occipital-nerve injections of novocain. Following this treatment, complete relief had been obtained in 49.6 per cent, partial relief in 29.5 per cent, and no relief in 5.7 per cent; in the remaining 15.2 per cent, the condition had recurred.

Transient Anterior Longitudinal Ligament Calcification. A Factor in the Etiology of Acute Neck Pain. Dr. John E. Stewart [36] presented two cases in which roentgenograms had demonstrated the presence of transient amorphous calcification in the anterior longitudinal ligament, just anterior to the dens of the second cervical vertebra. In both cases, the condition had been preceded by the development of sore throat and acute wryneck and the patient had felt occasional "catches" in the neck. One of the patients had been treated by ACTH (sixty units) and the other, who had a mild temperature, had been treated by Duricillin. In both cases, the sore throat and the wryneck symptoms had subsided within a few days, but the patient had continued to feel occasional mild cricks of the neck for several weeks. The calcific opacities and the thickened ligamentous shadow which had been apparent in the roentgenograms of one of the patients had disappeared.

This condition may be visualized only in lateral roentgenograms, and, in the interpretation of these roentgenograms, it is important to distinguish clearly between ear-lobe shadows and calcific deposits. In cases of acute neck pain, a diagnosis of this condition should be considered. When this condition is found, the use of such additional therapeutic measures as ACTH injections, local transoral radiation, and local infiltration through the pharynx should be considered as possible means to obtain more rapid relief of symptoms and cure.

Stiff Neck. Dr. Ralph C. Petersen (deceased) and Dr. Homer A. Graham [37] presented a series of pictures, diagrams, and roentgenograms showing human beings and animals in both relaxed positions and positions of tension such as are caused by emotion or readiness for combat. These illustrations demonstrated the role of the sensitive neck flexors in rapidly shifting the position of the neck from relaxed lordosis to flexion or kyphosis. It was pointed out that the symptoms of stiff neck found in emotionally disturbed patients without injury are the same as those which occur following whiplash or cervical-strain injuries—headache, pain, stiffness of the neck, and recurrent pain and numbness of the upper extremities. It was also pointed out that roentgenograms of the neck of emotionally disturbed patients usually show the same loss or reversal of lordosis as is seen in patients with typical whiplash injuries. On the basis of their studies the authors had concluded that only those vertebrates which can convert, rapidly and without injury, the position of the neck from lordosis to kyphosis are likely to survive. This basic sensitive, hair-trigger capacity of the neck of the vertebrate, including man, to mirror his emotions must be understood in the treatment of neck pain from any cause.

Cineplasty. A Critical Review of Sixty-Two Patients. Dr. Robert Mazet, Jr.[38] and Dr. Neil P. McCloy [39] presented a clinical analysis of the results obtained in sixty-two patients treated by cineplasty. Improvements in technique and in prosthetic devices have made cineplasty a more reliable treatment. The main differences between the present-day accepted technique and that of Sauerbruch is that the tunnels in the muscle used for a motor are longer and larger and that the distal end of this muscle is detached from its insertion.

Despite recent improvements in this method of treatment, careful selection of cases is still necessary. Before considering the operation, it is necessary to be sure that the amputee is intelligent and cooperative, that he understands the demands that will be imposed on him, that he has made good use of a conventional prosthesis for six months, and that he has known and talked with other cineplasty-prosthesis users.

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[34] 411 30th Street, Oakland 9, California.
[35] 354 21st Street, Oakland 12, California.
[36] 1012 Summit Avenue, Seattle 4, Washington.
[37] 324-B East Orange Grove Avenue, Burbank, California.
[38] Veterans Administration Hospital, Los Angeles 25, California.
[39] Veterans Administration Regional Office, San Francisco, California.

The most successful type of cineplasty is biceps cineplasty in the below-the-elbow amputee. In the authors' series, only 22 per cent of these operations had resulted in failures, as compared with 50 per cent of the pectoral cineplasties and 100 per cent of the forearm and triceps cineplasties. The incidence of failure in the total series was 39 per cent. The principal causes of failure in this series were injudicious selection of cases, lack of cooperation of the patient in learning to use the prosthesis, recurrent tunnel excoriation, closure of the tunnel, inefficiency of the prosthetic device, tunnels of insufficient size, and absence of need for this prosthesis in unilateral amputees. With current prosthetic techniques, holding tunnels are not necessary.

In his discussion, Dr. Ernest M. Burgess [40] agreed that the qualifications listed by the authors must be satisfied if the desired comfort, stability, and good appearance are to be obtained.

Col. H. W. Spittler [41], the second discussor, stated that in his experience success depends largely on proper "tailoring" of the tunnels. He felt that in a well equipped center cineplasty need not be delayed and that it should be recommended early rather than suggested on an elective and selective basis.

A Self-Contained Below-the-Knee Prosthesis. Dr. J. Warren White [42] and Dr. George K. Susat [43] had devised a method of holding a suction-socket below-the-knee prosthesis, a generally unsuccessful device, in close apposition to the stump of a child with a congenitally deformed foot. Five years before the time of writing, when the child was one year old, a skin loop had been constructed from the deformed foot, the toes of which had been sutured back onto the leg. A tendon element had not been included. Movies made shortly before the time of writing demonstrated that this arrangement functioned successfully during strenuous activity, even when the above-the-knee portion of the prosthesis was eliminated. The apparatus was attached to the skin loop by means of rubber tubing.

The only originality claimed by the authors was the idea of constructing a non-irritable loop out of the normal untransplanted skin of the deformed lower portion of the leg. This method of treatment should be considered in appropriate cases.

Subcapital Fractures of the Femoral Neck. Dr. D. Kay Clawson [44] reported a series of 333 hip fractures treated over a four-year period. These fractures had been divided into three groups—fractures of the base of the femoral neck, fractures of the mid-portion of the femoral neck, and fractures of the subcapital region.

In the subcapital group, follow-up had been maintained for two to six years, a period sufficiently long to permit substantial statistical analysis. The results had been classified on a functional basis: a rating of *1* had been given if the patient was confined to bed or to a wheel chair; a rating of *2* if the patient was able to walk with crutches or with two canes; a rating of *3* if he was able to walk without support, with little or no pain, and if he was completely self-sufficient; and a rating of *4* if the hip was essentially normal. Of the results 30.5 per cent had been rated *1*, 30.5 per cent *2*, 20 per cent *3*, and 19 per cent *4*, making a total of 61 per cent that were considered poor and 39 per cent that were considered satisfactory. In this group, the following complications had occurred: non-union in 26 per cent; aseptic necrosis in 10 per cent, resorption of the neck in 10 per cent, dissolution of the femoral head in 10 per cent, and infection in 3 per cent. Of eleven patients treated by the insertion of hip prostheses, seven had obtained satisfactory results.

The authors had concluded that the standard method used to treat these fractures will save the patient's life but that it is not entirely satisfactory. They also concluded that the insertion of a prosthesis is helpful but should not be done routinely as an initial procedure since the functional end result of a healed subcapital fracture is better than the result of any known type of arthroplasty.

Solitary Unicameral Bone Cysts. Dr. T. Wesley Hunter [45] presented the results of a careful follow-up study of twenty patients with unicameral bone cysts. These cases had been taken from a total series of twenty-seven cases.

The rate of recurrence in the group followed was 50 per cent, 64 per cent of these recurrences being in patients under fifteen years of age. The age range of the patients was from two years to fifty-three years and the location of the tumors was as follows: 74 per cent were in the humerus and femur, 15 per cent were in the ilium, 4 per cent were in the tibia, and a few others were in the metacarpals. Pathological fracture did not result in healing. On the basis of their statistical analysis of the results, the authors had concluded that the most practical method of treatment is curettement, chemical cauterization, and the insertion of bone chips. The possibility of recurrence is decreased by the performance of a secondary operation.

Correlation of Femoral Anteversion with Redislocation. Dr. William T. Kernahan, Jr.[46]

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[42] Straub Clinic, 1020 Kapiolani, Honolulu 14, Hawaii.
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[44] 525 Vidal Drive, San Francisco, California.
[45] University of California Medical Center, San Francisco, California.
[46] Primary Children's Hospital, Salt Lake City, Utah.

presented a study made in order to determine the correlation between the degree of femoral anteversion and the incidence of redislocation. In the first portion of his paper he described the embryological development of the hip joint, explaining why some hips subluxate anteriorly and others subluxate posteriorly. In the second portion of his paper he described a method of determining the degree of anteversion. In this method the patient is placed in a frame and lateral horizontal roentgenograms of each hip are made. Following this, anteroposterior roentgenograms are made with the transcondylar axis parallel to the x-ray table, and the projected angle of inclination of the femoral neck is determined. The degree of anteversion can then be calculated by means of the Ryder-Crane formula [a].

In the author's series the average degree of anteversion in hips which dislocated or subluxated following reduction was 63.4 degrees, the extremes being 33 and 90 degrees. The average degree of anteversion in hips which remained reduced without further treatment was 46 degrees, the extremes being 25 to 84 degrees. These findings suggest that subtrochanteric derotation osteotomy should be seriously considered following reduction of a congenitally dislocated hip if there is anteversion of over 30 degrees.

a. Ryder, C. T., and Crane, Lawrence: Measuring Femoral Anteversion: The Problem and a Method. J. Bone and Joint Surg., **35-A:** 321–328, Apr. 1953.

The Neurinoma in Clinical Orthopaedics. Dr. H. R. Noer [47] and Dr. T. S. Johnson [48] reported that of 3,500 neoplasms removed during a seven-year period, 1 per cent had been neurinomata of orthopaedic interest, and one out of six of these had been malignant. They also reported that only one out of four had been correctly diagnosed preoperatively. They claimed that neurinomata are peripheral-nerve tumors which are poorly understood; as evidence of this lack of understanding, they pointed out the many names which have been used to describe these tumors in the literature, the most common of these names being schwannoma, neurolema, neurinoma, neurofibroma, and perineural fibroma. On the basis of this study they had concluded that neurinomata are neuro-ectodermal in origin and occur either singly or in multiple fashion, as in von Recklinghausen's disease.

A report was given of the case of a four-year-old boy who had been crippled since birth. The diagnosis had been made when he was six months old. Following amputation, it had been found that the tumor had invaded not only all the soft tissues of the knee but also the adjacent bones.

The authors hoped their paper would bring attention to this tumor and increase the surgeon's awareness of it as a neoplasm with a high incidence of malignant growth.

Types of Athetosis. Dr. William L. Minear [49] and Dr. Winthrop M. Phelps [50] stated that athetosis is characterized by involuntary movements which are distinct from the spastic movements of other types of cerebral palsy. Athetosis may be classified in different ways, including on the basis of etiology, on the basis of the precise location of the involvement in the extra-pyramidal system, and on the basis of the degree of handicapping.

The authors suggested a fourth method of classification which is based on the type of motor involvement. They described twelve categories, the first five of which involve primary types of motion and the remainder of which involve special characteristics. These twelve categories are: rotatory movement; tremor-like movement; dystonia; shudder (flexion-extension); flail movement; tension; non-tension; hemiplegia; abnormal neck and arm movement; deafness; balance release; and emotional release.

The most common of these types is rotatory athetosis in which the involuntary movement consists in slow rotatory motions of the feet, hands, or shoulders. Almost as common is tremor athetosis which involves the flexor-extensor and abductor-adductor mechanisms. In the dystonic type the extremities are involuntarily held in distorted positions for periods of a few seconds to a few minutes, and in the shudder type the involuntary movements resemble normal responses to unpleasant sensory perceptions, these movements being especially noticeable when the patient writes or walks. The patient with flail athetosis throws his arms or legs about. This form is fortunately rare, for the patient usually dies before he reaches maturity. There is no shifting or alteration in the pattern of motor activity in patients with one of these five forms of the disease.

The remaining seven types of athetosis are distinguished by such characteristics as the degree of tension of the part of the body affected. A patient with one of these types may also show manifestations of the five types described above. Some shifting in the motor activity involved may occur, for a child born with non-tension athetosis may later have muscular tension. In some cases of tension athetosis, training may help to reduce the symptoms. Impairment of hearing which involves only the high pitched notes is usually caused by Rh incompatibility. The terms *balance release* and *emotional release* are self-explanatory. Patients with athetosis comprise 19 per cent of the total number of patients with cerebral palsy.

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In his discussion of this paper, DR. WILLIAM B. MCGRATH [51] compared the involuntary movements of the athetoid patient to the movements of a patient undergoing electric-shock treatment. He pointed out that the extra-pyramidal system is the source of nerve impulses for such automatic activities as walking and that its paralysis causes the disability of athetosis.

The Significance of Primitive Reflexes in Spastic Paralysis. DR. WILLIAM R. DUNCAN [52] and DR. RAYMOND J. ADAMS [53] pointed out that there are two primitive reflexes which may be important factors in patients with spastic paralysis. These reflexes are found in normal individuals as well as in patients with cerebral palsy and hemiplegia. From the standpoint of contracture development in pathological conditions, the more important of the two reflexes is the plantar thrust which results from upward pressure on the ball of the foot; this reflex produces contraction of the calf musculature. The second reflex, which is less well developed, is caused by pressure on the plantar surface of the heel and results in dorsiflexion of the ankle. The author's clinical observations concerning these reflexes had been corroborated by the findings of repeating stroboscopic photographs and electromyographic recordings demonstrating the action potentials of the involved musculature. Tests had been made on newborn infants, and it had been found that following exertion of pressure on the heel strong action potentials could be detected in the tibialis anterior but there was relative lack of response in the calf. Pressure on the ball of the foot had produced the opposite effect. In photographic and electromyographic studies of normal adults and children while walking, evidence of these reflexes had been found. Similar studies of patients with spastic paralysis had yielded similar results, and in patients with paraplegia the presence of these reflexes had been determined by means of clinical visual studies.

It was felt that the reflex response to pressure on the fore part of the foot corresponds to the positive supporting reaction described by Magnus. The dorsiflexor response to heel pressure had not been previously reported, however, probably because it does not exist in the lower primates upon whom the principal early observations had been made. In the normal individual the heel and toe reflexes may well play a part in making gait an automatic process.

On the basis of Sherrington's hypothesis that muscle contracture is the result of chronic stimulation of one reflex pattern at the expense of another, the author felt that the familiar calf contracture of infantile spastic paralysis is possibly the result of chronic stimulation of the reflex pattern of the fore part of the foot. In his clinical treatment of patients with spastic paralysis, he had used resistance exercises in which counterpressure was applied to the heel in order to activate the heel reflex and thereby improve dorsiflexor ability. He had also used calcaneus braces which hold the foot in a position of less than 90 degrees with relation to the leg in order to avoid repetitious application of pressure on the fore part of the foot; by this means he prevented stimulation of the plantar reflex during walking. Following this treatment he had noted improvement in the contracted gastrocnemius-soleus musculature and also spontaneous correction of the hamstring shortening, reducing the tendency toward bent-knee gait.

In his discussion, DR. WILLIAM B. MCGRATH [51] stated that two abnormal reflexes of the fore part of the foot are involved, one pyramidal and the other extrapyramidal. He was chiefly interested in the flexion of the toes which results from pressure on the metatarsal region and which he considers to be an extrapyramidal response and to be comparable to the grasping reflex of the hand.

Carcinoma and Stasis Ulceration. DR. JAMES S. MILES [54] and DR. HARRIETT JACKSON [55] reported three cases in which a carcinoma had developed in the tissues surrounding an area of chronic ulceration.

In the first case the patient was an eighty-one-year-old white woman who had come for treatment of ulcerations in both legs of at least thirty years' duration. She had had drainage from her forehead when four years old, drainage from her left knee when fourteen, and drainage from her left ankle when seventeen. The leg ulcers had recently caused increasing pain and a foul odor. Roentgenograms of the left tibia had revealed an osteolytic lesion under the ulcer. This lesion was surrounded by reactive periosteal new bone, a change which had also been seen in the right tibia. At operation the ulcers of both legs had been excised and the wounds had been covered with split-thickness skin grafts. Microscopic sections from the ulcer of the left leg had revealed a squamous-cell carcinoma with pearl formation invading and destroying the underlying bone. Two months later, following a pathological fracture of the left tibia, an above-the-knee amputation had been performed. The ulcer in the right leg had healed but had recurred after two months. The patient had died three months after the amputation as a result of carcinomatosis.

The second patient was a white woman sixty-eight years old. She had ulceration of the left leg of twenty-five to thirty years' duration and previously had had small ulcerations of her right leg which had healed. Examination had revealed a foul-smelling ulceration which covered the medial aspect of the distal one-half of the left leg and which was surrounded by hypertrophic keratotic-crusted tissue. A small ulcer had also

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been found on the right leg just above the medial malleolus. Roentgenograms of the left leg had showed only marked osteoporosis. Following débridement of the ulcer in the left leg, microscopic examination had revealed a low-grade squamous-cell carcinoma with pearl formation. The entire ulcer including a border of normal tissue had been excised and subsequently the wound had healed. During the following year, small recurrences of the ulcer on the left leg had been noted, and seventeen months after the first operation, a second excision with skin-grtfting had been done. Carcinoma had again been found. The ulcer had healed, and five months after the operation there had been no recurrence.

The third patient was a seventy-four-year-old woman with a varicose ulcer of the right leg of forty years' duration. Roentgenograms had revealed a large destructive process in the distal third of the right tibia, and a biopsy had revealed squamous-cell carcinoma. An immediate above-the-knee amputation had been done, following which there had been no local recurrence. Three months later, however, the patient had died as a result of adenocarcinoma of the colon with widespread abdominal metastases. No evidence of squamous-cell-carcinoma metastases had been found.

In his discussion of this paper, Dr. Leonard Barnard [56] pointed out the importance of chronic irritation in the development of certain types of lesions, including "chimney-sweep's" carcinoma of the scrotum, the carcinoma of the skin over the trochanteric area which is caused by the carrying of brick ovens, and the tropical ulcers of Africa. He stated that he believes neoplastic proliferation has a multiple rather than a simple origin.

Isolated Fractures of the Greater Trochanter. Dr. Robert E. Carlton [57] and Dr. James S. Miles [54] stated that there are two types of isolated fracture of the greater trochanter. The more common type is comminuted fracture as a result of direct trauma in older individuals, with little if any displacement of the fragments. The other type is avulsion of the greater trochanter as a result of indirect trauma in young adults, with varying degrees of displacement. In both types, the clinical findings resemble those of the more common types of hip fracture, and the diagnosis can be made only by roentgenographic study.

The authors presented a statistical analysis of twenty-nine fractures observed during a four-year period. Of these, twenty had occurred in males and only one was the result of indirect trauma. All of the patients had been treated by bedrest for a period of seven to ten days followed by partial weight-bearing with crutches or a cane until the pain had disappeared. The results had been entirely satisfactory. In sixteen of the eighteen patients followed, the results had been considered good and in the other two they had been considered only fair because of a slight persistent limp. In five cases the results had been recorded as good in spite of non-union of the greater trochanter. The authors concluded that the prognosis for this type of fracture is good, that the result has no relationship to the amount of displacement of the fragments, and that symptomatic treatment is sufficient to obtain a good functional result despite non-union of the fragments.

Dr. Alonzo J. Neufeld [58] and Dr. Francis E. West [59], the discussors, stated that they substantially agreed with the authors' findings and conclusions.

The Results of Therapy of Intertrochanteric Fractures at Denver General Hospital. Dr. Kenneth W. Olshausen [60] and Dr. James S. Miles [54] had made a statistical analysis of 203 intertrochanteric fractures in 197 patients (no two of the fractures had occurred simultaneously). One hundred and sixteen of the patients were women, and the great majority were between the ages of seventy and eighty-nine years. Only three fractures had failed to unite, and in these cases bone grafts had later been inserted, with unstated results. Twenty-seven of the patients, of whom twenty had been operated upon, had died thirty days after either admission or operation, and forty-five had died subsequently.

In the total series, 193 fractures had been treated by operation (usually by means of a Neufeld nail), five had been treated by skeletal traction, and five had received no therapy. In thirty of the cases in which operation had been done, the average period required for healing, as determined by means of roentgenograms, had been seven months. Some residual deformity had been found in 183 fractures.

In his discussion, Dr. Alonzo J. Neufeld [58] pointed out that in intertrochanteric fractures the results obtained by the two methods of treatment, open and closed, are very much alike as regards the final position of the femoral neck, the angle of the shaft, and the length of hospitalization. The chief advantage of internal fixation is that it permits early ambulation and thus minimizes the possibility of bed sores.

Dr. Francis E. West [59] called attention to the fact that the results obtained in this series by the two methods of treatment cannot be compared since the number of fractures treated by the closed method was too small for statistical evaluation.

Fracture-Dislocation of the Cervical Spine in Small Children. Dr. J. Irving Tuell [61] described

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[60] 2111 14th Street, Boulder, Colorado.
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two cases in which fracture of the odontoid process and forward dislocation of the first cervical vertebra had occurred in children. The patients, both seen personally by the author, were two years old and sixteen months old, respectively. In neither had any paralysis or sensory disturbance been observed, and in each reduction of the dislocation had been obtained by dependent-head traction and maintained by a Minerva plaster jacket, applied with the neck in a hyperextended position. After nine weeks this jacket had been removed and a Forrester collar or a sheet-wadding collar had been worn for another four weeks. No disability had resulted in either patient.

In his discussion, Dr. Donald W. Blanche [62] reported that during the preceding ten years four children had been treated at the Children's Hospital of Los Angeles for fracture-dislocation involving the odontoid process. In only one had there been spinal-cord damage. Dr. Blanche recommended that reduction be obtained by keeping the child in a recumbent head-dependent position for several weeks, following which a plaster jacket should be applied with the neck in a hyperextended position.

The High Cost of No Safety Belts. Dr. L. Stanley Sell [63] discussed the magnitude of the problem of motor-vehicle accidents. In Idaho Falls, a city of 25,000 people, 133 patients had been admitted to one hospital during one year as a result of car accidents. Two of these patients had become paraplegic and two had died; the cost of hospitalization alone had been $26,000. It was noted that one leading manufacturer of automobiles had reported that only 3 per cent of car purchasers are ordering safety belts installed at the factory. The author advocated that physicians wage a campaign to increase the use of safety belts which he feels will lower the incidence of motor-vehicle injuries by 50 per cent.

Hot Mineral-Water Baths in the Treatment of Orthopaedic Patients. Dr. Robert Bingham [64] and Dr. Frank S. Zach [65] reported their experiences at the Angel View Crippled Children's Foundation at Desert Hot Springs, California. There are many hot mineral springs in the United States, but at those in the western half of the country few orthopaedic surgeons or physiatrists are available for consultation and supervision of patients. Immersion in hot baths results in increased blood circulation, reflex dilatation of the peripheral arterioles and capillaries, and a rise in skin temperature; these effects in turn cause reduction in tightness of muscles and fascia, reduction in stiffness of joints, improved circulation in cold and pulseless extremities, reduction in calcium deposits in bursae and joints, healing of ulcers and indolent wounds, closure and healing of draining bone and joint infections, and relief of pain in gout, varicose ulcers, and all forms of chronic joint inflammation.

In addition to these orthopaedic conditions, many general disturbances of the circulatory and excretory systems are benefited by hot baths. The performance of underwater exercises for painful joints and paralyzed muscles is facilitated in hot mineral pools, and the muscle spasm of the acute stage of poliomyelitis is relieved by such baths as well as by hot packs. In many conditions underwater treatment is designated as pre-ambulation therapy.

The authors believed that in these baths some beneficial absorption of the minerals takes place through the skin and that there may also be some inhalation of chemical gases. They emphasized the importance of the cooperation of the orthopaedist with specialists in physical medicine, internal medicine, and pediatrics in the care of patients receiving treatment at mineral springs.

Dr. Charles L. Lowman [66], the first discussor, stressed the importance of pool therapy. He doubted whether the mineral content of the water was of real significance.

Dr. George L. Dixon [67], in his discussion, described the first known spa on the North American Continent. This spa was located eighty miles south of Mexico City and was mentioned by Cortes. Dr. Dixon believed that the chief value of these spas is that they serve as centers at which paralyzed patients can be treated by the combined efforts of orthopaedists, physiatrists, and trained technicians.

The next Annual Meeting of the Western Orthopedic Association will be held in Santa Barbara, October 20 through 24, 1957.

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[63] 500 Walnut Street, Idaho Falls, Idaho.
[64] 3536 Tenth Street, Riverside, California.
[65] 252 South Carondelet Street, Los Angeles 57, California.
[66] 2417 South Hope Street, Los Angeles 7, California.
[67] 744 North Country Club Road, Tucson, Arizona.

SOUTHERN MEDICAL ASSOCIATION

Section on Orthopaedic and Traumatic Surgery

The Golden Anniversary Meeting of the Southern Medical Association was held in Washington, D. C., November 12 to 15, 1956. Summaries of the papers read at the sessions of the Section on Orthopaedic and Traumatic Surgery follow:

Medullary Fixation in Fractures. Results in 100 Consecutive Cases. Dr. Robert C. Robertson [1] stated that open reduction and internal fixation should be restricted to fractures in which their use promises better functional results than can be anticipated by closed methods. Medullary nailing causes minimal circulatory damage at time of surgery and permits continuous compression between the fragment ends during healing. One hundred successive, unselected, medullary nailings performed between April 26, 1949, and March 12, 1955, on ninety-five patients between ten and seventy-six years of age were reported. There were seventy-three simple fractures, twenty-three compound fractures, and four previously infected fractures. Eighty-nine fractures were fresh, ten were ununited, and one was malunited. Thirty-six femora, thirty-five forearms, fourteen humeri, twelve tibiae, and three clavicles were involved. There were no deaths. Nail migration occurred in nineteen, non-union in eight, bending or breakage of the nail in five, moderately severe infection in one, perforation of the cortex by the nail in one, and refracture after removal of the nail in one.

Intramedullary fixation is the preferred method of treatment of displaced fractures of the shaft of the femur, and the bones of the forearm in the adult. It is rarely indicated in the treatment of fractures of other long bones.

Management of Difficult Fractures of the Femoral Shaft. Dr. Chalmers R. Carr [2] and Dr. R. E. Miller [3].

Intramedullary Fixation of Forearm Fractures. Dr. F. Wayne Lee [4] pointed out that the anatomical and physiological factors peculiar to the forearm make certain demands on the surgeon who employs intramedullary fixation of forearm fractures. In certain cases, the normal sequelae of delayed union, transient tenosynovitis, and prolonged immobilization may mitigate against routine acceptance of this procedure. It is the author's opinion that in most instances an attempt should be made at closed reduction before resorting to an open operation. Both axial and rotational alignment should be restored in each case, although the surgeon may accept less than perfect alignment in selected instances. The advantages of the technique and the possble pitfalls and complications were stressed. The importance of rigid fixation, proper immobilization, reinforcing cancellous bone, and meticulous surgical technique were emphasized.

Don't Open That Fracture. Dr. Samuel T. Moore [5] pointed out that from time immemorial fractures were treated by closed methods. The art of closed reduction had become a highly skilled and very efficient art during the late Nineteenth Century and early Twentieth Century. It was subsequent to that time that open reduction had grown in popularity and acceptance. The practitioner must bear in mind the functional result to be anticipated and not allow his judgement to be clouded by the roentgenogram and the tendency to treat the roentgenograms. The mismanagement of certain fractures, particularly in children, by the use of open reduction was illustrated. The student was urged to pay close attention to the pathophysiology of fractures and the manner in which reduction and immobilization of certain fractures by external means was carried out by the master surgeons of by-gone days. In closing, a plea was made to face the issue of delayed union and non-union squarely, recognizing the fact that these complications result from failure to give due consideration to the anatomical and mechanical features of the fractures rather than from a disordered physiology.

Segmental Fractures of the Tibia. Dr. B. F. Boylston [6] and Dr. Robert W. Milam [7].

Conservative Management of Fractures of the Shaft of the Tibia and Fibula. Dr. Earnest B. Carpenter [8] and Dr. John F. Butterworth, III [9] decried the widespread use of internal fixation in the treatment of fractures of the shaft of the tibia and fibula. They re-emphasized the need for a more con-

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[2] 123 West Seventh Street, Charlotte 2, North Carolina.
[3] Charlotte, North Carolina.
[4] 225 Hawthorne Lane, Charlotte, North Carolina.
[5] 411 N. W. 11th Street, Oklahoma City 3, Oklahoma.
[6] Baylor University College of Medicine, Houston, Texas.
[7] Houston, Texas.
[8] Medical College of Virginia Hospital, Richmond, Virginia.
[9] Medical College of Virginia Hospital, Richmond, Virginia.

servative approach in the management of such fractures, stating that a great majority of fractures of the tibial shaft can be handled by conservative means with less danger of complications and with better end results. It was pointed out that many men in training are unduly influenced by reports of the more dramatic use of internal fixation. The use of internal fixation, when indicated, is a procedure to be undertaken only by the experienced orthopaedic or traumatic surgeon. The use of the Mauck traction hitch for closed reduction of fractures of the tibial shaft was reviewed; it was emphasized that the use of a lightly and tightly padded, *snugly applied thin cast* is very important in the maintenance of reduction obtained by this method. The flexed knee position in the cast is important in the maintenance of position in shaft fractures of the tibia. The indications for the use of certain types of internal fixation in specific instances were unquestioned.

Fractures about the Hand. Dr. Daniel C. Riordan [10].

Power-Motor Injuries. Dr. George R. Miller [11].

The Painful Shoulder. Its Etiology, Pathology, Diagnosis, and Treatment. Dr. W. McDaniel Ewing [12] dealt with lesions producing shoulder pain which often result in joint stiffness. Shoulder pain resulting from cervical-disc syndrome and from pathological conditions of bone was excluded. The anatomy of the shoulder was reviewed as it pertained to function of the joint. The review emphasized the formation and function of the fibrotendinous cuff of the shoulder. The capsule and fibrotendinous cuff were involved in the greatest number of the lesions discussed. The work of Nicola, in which the most common causes of pain and stiffness in the shoulder were set forth, was reviewed. Variations in the anatomy of the shoulder which might cause degenerative lesions, as discussed by DePalma, were outlined.

The lesions were discussed as regards age, onset, relation to injury, localization of tenderness, and the performance of certain movements. The treatment of the lesions was fully set forth, including the use of hydrocortone injections.

Malum Gleni Senilis. Dr. Lee T. Ford [13] and Dr. Wayne Simril [14] reported ten cases of degenerative arthritis of the shoulder joint. The condition is seen much less frequently than degenerative arthritis in the hip. Degenerative arthritis may be localized in the shoulder joint or joints and may resemble malum coxae senilis. In one patient an infection of the shoulder during childhood was felt to be a cause, while in another patient surgery for recurrent dislocation seemed to be a factor. One patient felt an injury to her arm was responsible for the condition. In the remaining patients, the etiology was unknown. Five patients were male and five were female. The cases reported varied from mild to severe. In severely involved patients there were joint-space narrowing, sclerosis, and spurring; these were complicated by painful limitation of motion. Treatment, with one exception, was conservative. It consisted in the use of salicylates, heat, exercises, intra-articular injection of hydrocortisone, and manipulation under anaesthesia. In one patient, because of recurring hemarthrosis, exploratory arthrotomy and a partial synovectomy were carried out.

The Winged Scapula. Dr. Donald J. O'Brien [15] reported that during four years in a small urban area fifteen cases of winged scapula were recognized. It seems evident that with greater attention winged scapula would be diagnosed much more frequently. In the majority of the patients reported the condition had been recognized for a long time. Pain anywhere in the region of the shoulder girdle may be experienced. Patients were divided into two groups: (1) those with recently developing conditions and (2) those with chronic recurrences. Dr. O'Brien stated that he had had little experience with the recently developing condition. Most of his patients had had the condition for various periods of time—some for twenty years or more. He had attempted to determine what symptoms were associated with chronic weakness of the serratus anterior. All of the patients had incomplete palsy which rendered diagnosis difficult. Treatment was briefly discussed. Disability resulting from this condition, especially when incomplete paralysis exists, is not great for any but the manual laborer.

The Diagnosis and Treatment of Ruptures of the Rotator Cuff. Dr. James E. Bateman [16].

Coccygectomy. Dr. John A. Powers [17].

Use of the Tourniquet in the Lower and Upper Extremities without General Anaesthesia.

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[14] St. Louis, Missouri.
[15] 401 East Tuscaloosa Street, Florence, Alabama.
[16] Medical Arts Building, 170 St. George Street, Toronto, Ontario, Canada.
[17] 1500 Elizabeth Avenue, Charlotte 4, North Carolina.

Dr. R. W. Coonrad [18] and Dr. W. E. Knight [19] reported that use of the tourniquet in both lower and upper extremities with local anaesthesia is not extensive. Tourniquet pain attributed to ischaemia of the larger nerve trunks can be adequately controlled by demerol analgesia. The drug is given intravenously at the time of tourniquet inflation.

One-hundred milligrams of demerol given intravenously in the average adult is sufficient for analgesia; this allows an average of thirty to forty minutes in the lower extremity and forty to sixty minutes in the upper extremity before any discomfort occurs from the tourniquet. Premedication with barbiturates and hyoscine frequently allows the patient to sleep during the procedure. Eighty-seven procedures in the upper extremity and 122 procedures in the lower extremity were satisfactorily performed in this manner; these included twenty arthrotomies of the knee. The patients' ages varied from ten to seventy years. The authors concluded that the tourniquet can be used satisfactorily (1) when complete muscle relaxation is not required, (2) when operative time can be predetermined, and (3) without the associated risk of pneumothorax and other complications associated with the brachial plexus in the upper extremity. It should be contra-indicated in emotionally unstable patients and is not recommended for repair or grafting of the flexor tendons in the hand. It is not recommended for routine use in knee arthrotomy, but arthrotomy can be carried out by use of this method when the diagnosis has been established.

Flexion Thumb in the Infant. Dr. Lyon K. Loomis [20] reviewed the clinical and pathological findings of a typical condition which appears in infants—stenosing tenosynovitis of the flexor pollicis longus. Although the condition has been referred to as trigger-finger, snapping is often not present. If the attending physician is not familiar with the condition, such diagnoses as residual poliomyelitis and dislocation at the interphalangeal joint may be entertained. If the physician is familiar with the condition, diagnosis and treatment are simple and postoperative results good.

Patellectomy. Dr. George Miyakawa [21] stated that patellectomy can be expected to alleviate only those symptoms which are directly caused by pathological changes in the patella itself. In many old internal derangements of the knee, one finds a co-existing rupture of a meniscus, free bodies, malacic changes of articular cartilages of the femur or tibia, osteophyte formation, and even relaxation of the cruciate and collateral ligaments. Various forms of repair of the rent in the extensor apparatus following patellectomy have been advocated. In Dr. Miyakawa's experience, limitation of complete flexion was noted when the quadriceps tendon was sutured to the patellar tendon. Loss of complete extension occurred when the rent was closed from side to side or when no attempt was made to obtain continuity between quadriceps and patellar tendons. Heterotopic bone formed in the extensor apparatus.

The author presented a motion picture showing a technique in which a tongue of the quadriceps tendon is turned down and sutured to the patellar tendon; this left approximately the same space as that originally occupied by the patella. By this method no loss of flexion or extension has occurred. In order to avoid heterotopic-bone formation, the removal of the patella is performed by sharp dissection and a periosteal elevator is never used. In this manner no nidus of bone is left to act as a focus of heterotopic-bone formation.

Fractures of the Femoral Condyles. Experiences with a New-Design Femoral-Condyle Blade Plate. Dr. Robert E. Elliott [22] pointed out the difficulties encountered in obtaining and holding reduction of comminuted and intra-articular fractures of the femoral condyles, the long treatment required, the common complication of non-union, and the usual loss of knee motion which results. A newly designed femoral-condyle blade plate, combining the V-blade of Neufeld, to hold the condyles, with the slotted plate of Eggers was presented. This was developed in order to obtain contact compression in the supracondylar region and in the shaft. During the past three years, with use of the blade plate twenty times in nineteen patients, in all types of condylar and supracondylar fresh fractures and in supracondylar non-union, there were no cases in which non-union occurred or persisted. Little or no external fixation or support was used and the hospital stay was considerably shorter compared with that of patients treated by traction. He felt that the average healing time was somewhat shorter than formerly noted.

In all patients upon whom follow-up was possible, a good range of knee motion resulted. Many of these had had severe T and Y fractures; in these a nearly normal range of knee flexion and full extension were present. The anterolateral operative approach, the anatomical restoration and reduction, the early institution of knee motion and exercises, and the avoidance of casts and traction were emphasized as being of importance in obtaining the excellent results reported.

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[21] 317 Atlas Building, Charleston, West Virginia.
[22] 217–219 Medical Arts Building, Houston 2, Texas.

Avascular Necrosis of the Head of the Femur. A Study with Radioactive Phosphorus (P^{32}). Dr. R. A. Calandruccio [23] and Dr. D. B. Zilversmit [24] used radioactive phosphorus to develop a method whereby at the time of internal fixation of an acute fracture of the neck of the femur one could anticipate the development of avascular necrosis of the femoral head. Counting rates were determined by placing a Geiger probe in the head and trochanter.

Femoral heads containing P^{32} were obtained from thirty-seven patients with acute femoral-neck fractures. In 40 per cent of these there was little radioactivity. In 60 per cent there was less radioactivity in the superior or weight-bearing area than in the remainder of the head. (In dogs with no impairment of blood supply, there was less radioactivity in the posterior-superior aspect of the head.) Counting rates then should be determined in the superior aspect of the femoral head.

Specimens were also obtained from patients with avascular necrosis of the femoral head, degenerative arthritis, and non-union of the femoral neck. The distribution of radioactivity was determined by autoradiograms and counting rates. There was a definite lack of radioactivity in the areas of avascular necrosis. (In non-union of the femoral neck, roentgenograms are often misleading as to the viability of the head.)

Fusion of the Charcot Knee. Dr. Earl P. Holt, Jr.[25], proposed, as a result of five successful arthrodeses in four patients, a more optimistic outlook for successful fusion of the Charcot knee. A review of results reported by eight surgeons in the past twenty-five years revealed that of forty-three Charcot knees operated upon, in only fourteen or 30 per cent did proved bony ankylosis occur.

Evidence had accumulated that positive pressure, as introduced by Key and advanced and popularized by Charnley, greatly enhanced the chances of fusion of a knee. In four of the five knees, an intramedullary nail was added to a variety of positive pressure devices for additional stabilization. The advantages of a Rush femoral nail introduced through a window in the tibial cortex were discussed. Toe-to-groin casts incorporated the positive-pressure apparatus and were left on the extremities after removal of the positive-pressure apparatus until fusion of the knee had resulted.

The average length of time required for fusion was four and one-half months. One of the cases was reported in detail—that of bilateral Charcot knees in a fifty-one-year-old woman. Her right knee was fused in January 1951, and was still solidly fused five years afterward. The left knee was fused in April 1953, and was still solid three years afterward.

The Radiographic Criteria and Clinical Aspects of the Analysis of the Foot in Infants. Dr. William S. Hatt [26] and Dr. Lawrence A. Davis [27] recommended a method by which it is possible to analyze the medial and lateral longitudinal arches, the anterior and posterior aspects of the foot, and its medial and lateral borders, despite the poor ossification of the bones in the infant foot. Mid-talar and mid-calcaneal lines were described for both the anteroposterior and lateral roentgenograms and the position of these lines in the normal foot was described. The analysis of the fore part of the foot involved the projection of these lines and of lines through the first and fourth metatarsals.

Congenital talipes equinovarus may be primary or secondary. Statistics which do not differentiate between the various types of club-foot are of very little value. Classic club-foot is said to consist of three component parts: adduction, inversion, and equinus. Further studies revealed that there are actually, as seen roentgenographically, at least five component parts. The first three have already been mentioned; the fourth is equinus deformity of the fore part of the foot or cavus; and the fifth part is equinus deformity of the hind part of the foot previously undescribed, which involves a change in the relationships, as seen in the lateral roentgenograms, between the mid-talar and mid-calcaneal lines. Thus, there is ankle or talotibial equinus deformity, calcaneal equinus deformity, and cavus deformity.

The roentgenographic appearance of concave inner border (adduction of the fore part of the foot), supination of the fore part of the foot, cavus, and equinus deformity of the hind part of the foot were described. Rocker bottom (J. R. Moore) is a disease of the lateral longitudinal arch. The roentgenographic appearance of inversion of the heel, concave inner border, and prominence of the base of the fifth metatarsal in this condition was described. The roentgenographic appearance corresponding to increased heel flare, valgus heel, everted heel, convex inner border, and loss of the medial longitudinal arch was described for congenital flat-foot. Flat-foot with a normal appearance of the posterior portion of the foot may be referred to as metatarsus valgus or metatarsus abductus. The roentgenographic appearance of metatarsus varus was delineated as was that of cavus.

It is felt that comprehensive analysis of the positional changes in the infant foot will prove to be essential for the accurate diagnosis and treatment of the conditions mentioned, as well as for future investigation.

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[26] 1922 Hillview Street, Sarasota, Florida.
[27] Louisville, Kentucky.

The Chairman's Address. Posterior Dislocation of the Shoulder. DR. S. BENJAMIN FOWLER [28].

Syndactylism. DR. J. HIRAM KITE [29] reported a study of children with congenital deformities of the arm and hand in 13,000 orthopaedic cases seen at the Scottish Rite Hospital for Crippled Children. There were 166 cases which were divided into twenty-eight groups. The largest group of children had syndactylism (seventy-seven cases, 47 per cent). It is usually considered that the defect is inherited in only 5 to 7 per cent of the cases. The parents or grandparents of 30 per cent of these children had syndactylism. It has been stated that the webbing occurs most frequently between the middle and ring fingers. In this group, when only two fingers were involved, the index and middle fingers were fused eleven times, the middle and ring fingers thirteen times, and the ring and little fingers fourteen times. The thumb was fused to the index and other fingers in two cases. The index, middle, and ring fingers were fused together three times, and the last three fingers, five times. In seven cases all four fingers were fused together like a "mitten". Syndactylism is frequently associated with ectrodactylia or hypodactylia. In thirty-eight cases the fingers were normal in appearance and in thirty-nine the fingers were deformed. Syndactylism is frequently associated with deformities in other parts of the body. In forty-eight cases there were other deformities. There were eleven with syndactylism of the toes. Ten had club feet. Four had annular grooves of the extremities. Four had hare-lip and cleft-palate. Three had deformities of the face. Three had extra fingers, and three had extra toes. Three had an absence of one or more toes. Two had metatarsus varus deformity, and two had Mongolism. One patient each had deformities of the ribs, hips, and ulna, and one had absence of the other hand. The operation of choice is to turn up a U-shaped flap from the dorsum of the fingers, leaving the pedicle proximal to cover the commissure. The skin incision separating the fingers is zig-zagged on the palmar surface, and the denuded areas are covered with full-thickness skin grafts from the groin.

Hereditary Spastic Paraplegia. DR. F. JAMES FUNK, JR.[30], reported the case of a twenty-one-year-old workingman with multiple deformities of the lower extremities associated with spastic paraplegia. He gave a history of an essentially normal early childhood with the development of spasticity during his later childhood and adolescence. The family history revealed that two of his sisters and his mother had similar problems. After a neurological examination, a series of orthopaedic procedures were performed to enable him to walk in an upright position. Following his treatment, his family was investigated and data on forty-seven members were obtained, nineteen of whom had a history of paraplegia of some degree.

Familial or hereditary paraplegia is a variable disease, as usually reported, beginning, typically, with degeneration of the pyramidal tracts with gradual paraplegia. In some patients it begins in early life and is a gradually progressive disease often ending with dementia and mental changes. Other types have been reported in which the onset is during adolescence or early adult life. In some families this has been a sex-linked trait; usually it is a Mendelian recessive trait. In some instances its manifestations are difficult to separate from such diseases as Friedreich's ataxia or Charcot-Marie-Tooth disease. In general it is felt that this is a disease of unexplained etiology.

In the family in question, several interesting facts were uncovered. First of all, it is larger than any family that the author has found described in the literature. Secondly, unlike most of the reported types, in this family the condition seems to become arrested in early adult life and without subsequent progression. Finally, the history obtained from the members of the family indicates that this disease first appeared as a result of an unusual mating. A man had a daughter by his own daughter and this child subsequently married a man who was half-brother and half-uncle to her. As a result of this incestuous union this trait apparently originated.

In this very large family, the disease is particularly interesting, for it is not a Mendelian recessive trait, it is not sex linked, and it does not seem to be progressive.

Orthopaedic Aspects of Motor Vehicle Accidents. DR. JACOB KULOWSKI [31].

Plantar Interdigital Neuroma. DR. THOMAS L. DUNCAN [32] and DR. JOHN L. WRIGHT [33].

The new officers for the Section on Orthopaedic and Traumatic Surgery are: *Chairman:* Milton S. Cobey, M.D., Washington, D. C.; *Vice-Chairman:* J. Leonard Goldner, Durham, North Carolina; and *Secretary:* Daniel C. Riordan, New Orleans, Louisiana.

The next Annual Meeting of the Southern Medical Association will be held in Miami Beach, Florida in November 1957.

[28] 1921 Broadway, Nashville 4, Tennessee.
[30] 384 Peachtree Street, Atlanta 8, Georgia.
[31] 2515 Francis Street, St. Joseph, Missouri.
[32] Prytania and Aline Streets, New Orleans 15, Louisiana.
[33] New Orleans, Louisiana.

HIRAM WINNETT ORR

1877–1956

Nebraska and the Midwest great plains states lost one of their outstanding pioneers in orthopaedic surgery in the passing of H. Winnett Orr on October 11, 1956.

For nearly a half a century, he was a powerful force in every controversial issue concerning medicine. His administrative and organizational ability was recognized and esteemed. He was a tireless worker for the cause of crippled children, and, in 1905, when the Nebraska Orthopaedic Hospital was opened, he was placed in charge as Superintendent. In 1919, he became its Chief Surgeon, and he served in this capacity until 1947. Until his last illness, he maintained an important active relationship with this Institution, which is truly a monument to his efforts. In 1955, fifty years of crippled children's services in the State of Nebraska under his leadership were celebrated.

During his entire medical career he was a consistent worker in organized medicine. He was particularly active in promoting orthopaedic surgery in the State of Nebraska, and he was a prodigious contributor to medical literature.

Perhaps, his most distinguished contribution to orthopaedic surgery was the courageous battle he waged against osteomyelitis. The Orr treatment became the accepted therapy for this affliction and saved many limbs from long, painful, hopeless infection and even amputation. Although chemotherapy and antibiotics have virtually eliminated osteomyelitis, even now certain open wounds are treated by packing with non-adherent gauze, infrequent dressings, and immobilization—all of which are recognized as sound mechanical measures of management in the care of lacerated and fractured extremities.

Orthopaedic gatherings in this country and abroad will miss Dr. Orr and his active participation in every discussion. His caustic criticism and sharp tongue were usually tempered promptly with friendly commendations, an affectionate gesture, or a kindly deed.

His hobby and greatest outside interest was medical history, particularly in its relation to the local

scene and to orthopaedic surgery throughout the world. This became almost a passion with him and led him to countless libraries and book shops throughout this country and in Europe. His knowledge and his cultivated taste enabled him to recognize and acquire choice volumes and rare editions. Today, his library contains one of the finest collections of orthopaedic literature in the country and represents a large unselfish personal investment. It has been divided between the Library of the University of Michigan College of Medicine (his Alma Mater) and the Library of the American College of Surgeons in Chicago.

During his travels he became interested in Anne of Brittany and he became a devoted student of her life. The Love Library of the University of Nebraska set aside a Seminar Room for preservation of the Anne of Brittany collection, and Dr. Orr set up a trust fund to maintain this project.

One of his colleagues who worked with him for many years said, "I am sure I can voice for all of us our admiration for his forging ahead with earnest convictions, his tremendous potential and vitality, his ability as an author and student of orthopaedic history, and his surgical creative initiative. He was always a dominant factor in his surroundings."

Fortunately, Dr. Orr made life easier for himself in his advancing years. His summer home in the mountains gave him quiet and recreation. Although, in his earlier life, golf was his chief outdoor activity (he played an enviable game), in the mountains he took up fishing. However, most of his time was spent in his studies, reviewing the literature, and visiting his beloved children and his many grandchildren.

Hiram Winnett Orr was born in West Newton, Pennsylvania, March 17, 1877. He was graduated from the University of Nebraska in 1895 and from the University of Michigan Medical College in 1899. He married Grace Douglass on September 7, 1904.

Dr. Orr began his practice in Lincoln in 1899. He edited the *Western Medical Review* from 1899 to 1906, and *The Journal of Orthopaedic Surgery* from 1919 to 1921. He was author of *History of the Nebraska State Medical Society* (1903), *The Rights of the Patient* (1920), *Civilian Surgeon's Story of the Great War* (1921), *Drainage and Rest in the Treatment of Infection* (1927), *Osteomyelitis and Compound Fractures* (1929), *Hugh Owen Thomas, Sir Robert Jones, and John Ridlon* (1949), and numerous other contributions to medical literature. He was much sought after as a lecturer at medical meetings throughout the country and he was the guest of numerous foreign medical societies. In 1944, he wrote *Anne of Brittany*.

Dr. Orr was among the first to volunteer for service with the British in World War I before the United States had entered the conflict. With the establishment of the American Expeditionary Forces, he served in France as Consulting Orthopaedic Surgeon and had, in addition, a hospital assignment. In 1919, he returned to his practice in Lincoln but retained the commission of Colonel in the Reserve Medical Corps.

He was active in teaching the History of Medicine in the College of Medicine at the University of Nebraska (since 1903) and in graduate training in Orthopaedic Surgery at the Nebraska Orthopaedic Hospital. In addition to his active service at the State Orthopaedic Hospital he was for many years Chairman of the Orthopaedic Section of the Lincoln General Hospital, and he was on the Attending or Consulting staffs of St. Elizabeth's Hospital, Bryan Memorial Hospital, and the Veterans Administration Hospital of Lincoln.

As a member of the Nebraska State Medical Association, he served as Librarian, Secretary, and President; he served at one time as Chairman of the Orthopaedic Section of the American Medical Association. He served as Secretary and President of the Central States Orthopaedic Club, now the Clinical Orthopaedic Society, and he served as Secretary and President of The American Orthopaedic Association.

He was a fellow of the American College of Surgeons and was always active in the affairs of this organization. He was a member of the International Society of Orthopaedics and Traumatology.

He was a member of Chi Phi, Phi-Rho Sigma, and was an honorary member of Sigma Xi and Alpha Omega Alpha. He was active in local clubs and civic endeavors.

Dr. Orr enjoyed a full life and he derived great satisfaction from his activities. He now rests after fitting military interment in Arlington Cemetery, Washington, D. C.

News Notes

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Seventieth Annual Meeting of The American Orthopaedic Association will be held at The Homestead, Hot Springs, Virginia, June 24 to 28, 1957, under the presidency of David M. Bosworth, M.D. The tentative program of the Annual Meeting as submitted by the Program Committee is as follows:

Monday, June 24

9:00 A.M.

Capsulotomies of the Tarsometatarsal Joints for the Correction of Residual and Resistant Adduction of the Forefoot in Congenital Clubfoot or for Congenital Metatarsus Varus.
Clarence H. Heyman, M.D., and Charles H. Herndon, M.D., Cleveland, Ohio.

The Operative Management of Central Fractures of the Acetabulum.
Robert A. Knight, M.D., and Hugh Smith, M.D., Memphis, Tennessee.

The Histochemistry of Bone Repair.
Mr. R. B. Duthie, Edinburgh, Scotland.

Guest speaker: To be announced.

Report of Exchange Fellows' Visit to Great Britain.

Unicameral Cysts of the Long Bones: Treatment by Crushing Cystic Walls and Onlay Grafts.
Carl E. Badgley, M.D., Ann Arbor, Michigan.

Executive Session.

Tuesday, June 25

9:00 A.M.

A Report of Forty Cases of Impacted Fracture of the Femoral Neck Treated without Fixation.
Henry B. Crawford, M.D., Rochester, New York.

Femoral Neck Fractures: Pathogenesis of Aseptic Necrosis, Non-Union, and Late Degenerative Changes.
Sherman S. Coleman, M.D., and Clinton L. Compere, M.D., Chicago, Illinois.

Introduction of Circulation into the Necks of Femora.
Charles J. Frankel, M.D., David V. Strider, M.D., and W. Clarke Pole, M.D., Richmond, Virginia.

Torsion of the Femur. A Five-Year Report on the Use of the Dunlap Method for its Determination.
A. R. Shands, Jr., M.D. and Marshall K. Steele, M.D., Wilmington, Delaware.

The Significance of Femoral and Humeral Torsion.
William J. Tobin, M.D., Washington, D. C.

Address by the Vice-President: Charles Le Roy Lowman, M.D., Los Angeles, California.

Wednesday, June 26

9:00 A.M.

Residual Disabilities of the Neck and Low Back from Motor Vehicle Injuries.
Jacob Kulowski, M.D., St. Joseph, Missouri.

A Critical Analysis of Methods of Fusion for Scoliosis. An Evaluation of Results in 300 Patients.
John H. Moe, M.D., Minneapolis, Minnesota.

Cervico-Occipital Fusion.
Paul R. Lipscomb, M.D., Rochester, Minnesota.

The Iliotibial Band. Clinical and Morphological Significance.
Emanuel B. Kaplan, M.D., New York, N. Y.

Address by the President: David M. Bosworth, M.D., New York, N. Y.

Thursday, June 27

9:00 A.M.

Suppurative Arthritis of the Hip in Premature and Neo-Natal Infants.
Benjamin E. Obletz, M.D., Buffalo, New York.

The Synovial Membrane in Epiphysiolysis of Adolescence.
George J. Garceau, M.D., and Robert Morrow, M.D., Indianapolis, Indiana.

Acquired Dislocation of the Hip in Cerebral Palsy: Etiology, and Clinical Types.
Winthrop M. Phelps, M.D., Baltimore, Maryland.

The Surgical Correction of Congenital Elevation of the Scapula (Sprengel's Deformity).
William T. Green, M.D., Boston, Massachusetts.

Second Executive Session.

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

The Twenty-fourth Annual Meeting of The American Academy of Orthopaedic Surgeons was held at the Palmer House, Chicago, January 26 through 31, 1957, under the Presidency of Dr. William T. Green.

At the Second Executive Session, the new President, Dr. Frederic C. Bost, San Francisco, California, was inducted into office; the following officers and committeemen were elected:

President-Elect: H. Relton McCarroll, M.D., St. Louis, Missouri
Vice-President: Leo S. Lucas, M.D., Portland, Oregon
Treasurer: Jesse T. Nicholson, M.D., Philadelphia, Pennsylvania
Secretary: Clinton L. Compere, M.D., Chicago, Illinois
Librarian-Historian: Albert C. Schmidt, M.D., Milwaukee, Wisconsin

Executive Committee:
Francis M. McKeever, M.D., Los Angeles, California
Harold B. Boyd, M.D., Memphis, Tennessee
T. Campbell Thompson, M.D., New York, N. Y.
Walter P. Blount, M.D., Milwaukee, Wisconsin
William T. Green, M.D., Boston, Massachusetts

Junior Members of the Executive Committee:
Albert B. Ferguson, Jr., M.D., Pittsburgh, Pennsylvania
Herbert Pedersen, Dearborn, Michigan

Member of Membership Committee: Paul E. McMaster, M.D., Beverly Hills, California
Member of Committee on Scientific Investigation: Charles H. Herndon, M.D., Cleveland, Ohio
Member of Committee on Public Relations: John J. Hinchey, M.D., San Antonio, Texas
Member of Committee on Instructional Courses: Robert Mazet, Jr., Los Angeles, California
Member of Committee on Audio-Visual Education: Robert J. Joplin, M.D., Boston, Massachusetts

Nominated Representatives to the American Board of Orthopaedic Surgery:
Harry D. Morris, M.D., New Orleans, Louisiana
Lenox Baker, M.D., Durham, North Carolina

Dr. Keene O. Haldeman was appointed Chairman of the Program Committee and Dr. Carroll B. Larson was appointed new member of that Committee.

Immediately preceding the First Executive Session on Sunday afternoon, January 27, the following new members were inducted:

Seymour L. Alban, M.D., Long Beach, California
Henry W. Apfelbach, M.D., Chicago, Illinois
Cloyd Loren Arford, M.D., Greeley, Colorado
Albert Sterling Atwood, M.D., Torrington, Connecticut
Borden Bachynski, M.D., Regina, Saskatchewan, Canada
William Atherton Baird, M.D., Ames, Iowa
James Van Horne Ballantyne, M.D., Pittsburgh, Pennsylvania
John William Baluss, Jr., M.D., Fayetteville, North Carolina
Henry H. Banks, M.D., Boston, Massachusetts
John Roland Barber, M.D., Windsor, Ontario, Canada
George Bayne Barnes, M.D., Corpus Christi, Texas
Walter Prothro Barnes, Jr., M.D., Macon, Georgia
Ben Tertius Bell, M.D., Abington, Pennsylvania
Martin Leonard Beller, M.D., Philadelphia, Pennsylvania
Thomas C. Bolton, M.D., Medford, Oregon
Frank John Boutin, M.D., Woodland, California
Richard A. Bragdon, M.D., Boston, Massachusetts
Thomas Hartwell Brown, Jr., M.D., Toledo, Ohio
Frank Harding Burchell, M.D., Ridgewood, New Jersey
Billie Dee Burdeaux, Jr., M.D., Houston, Texas
C. Nason Burden, M.D., Taunton, Massachusetts
Donald Owen Burst, M.D., St. Louis, Missouri
George R. Callender, Jr., M.D., Charleston, West Virginia
Gerald Edward Callery, M.D., Philadelphia, Pennsylvania
Bruce Molloy Cameron, M.D., Houston, Texas
Maurice Emmett Castle, M.D., Detroit, Michigan
Howard Sprague Caukin, M.D., Grand Rapids, Michigan

Doris Elizabeth Chambers, M.D., Lebanon, Pennsylvania
Mentor Halfdan Christensen, M.D., St. Paul, Minnesota
Stephan A. Christides, M.D., Philadelphia, Pennsylvania
Ralph Citron, M.D., Amarillo, Texas
William Lorin Clark, M.D., San Francisco, California
Lawrence J. Cohen, M.D., Portland, Oregon
Victor P. Conforti, M.D., Torrington, Connecticut
Ralph W. Coonrad, M.D., Durham, North Carolina
Francis V. Costello, M.D., Williamsport, Pennsylvania
John A. Crawford, M.D., Indianapolis, Indiana
Paul Herbert Curtiss, Jr., M.D., Cleveland, Ohio
Thomas Barker Dameron, Jr., M.D., Raleigh, North Carolina
Roy N. Davis, M.D., San Antonio, Texas
William Monroe Davis, M.D., Akron, Ohio
Joseph P. Demeri, M.D., Richmond Hill, New York
Thomas Charles Devlin, M.D., Freeport, Illinois
Philip Hugh Dickinson, M.D., San Diego, California
Willard Edgar Dotter, M.D., Great Falls, Montana
Harold J. Eisenberg, M.D., Oakland, California
Michael Richard Ettenson, M.D., Poughkeepsie, New York
Paul Daley Everest, M.D., Montgomery, Alabama
Gordon N. Farner, M.D., Cleveland, Ohio
Richard Lewis Fenton, M.D., New York, N. Y.
Harry Fisher, M.D., Pittsburgh, Pennsylvania
Robert H. Fitzgerald, M.D., Independence, Missouri
Forrest Harold Foreman, M.D., Miami, Florida
Robert T. Gallagher, M.D., Cincinnati, Ohio
John Stuart Gaul, Jr., M.D., Charlotte, North Carolina
Don B. Gibboney, M.D., Beverly Hills, California
James Gilly, M.D., Lafayette, Louisiana
James Roger Glessner, Jr., M.D., Middletown, Connecticut
Stephen Henry Glucroft, M.D., West Hempstead, New York
Paul Goetowski, M.D., Lincoln, Nebraska
Elizur Raymond Goodrich, M.D., Huntington, New York
John Mason Gosslee, M.D., Shreveport, Louisiana
Nathaniel Gould, M.D., Brockton, Massachusetts
William R. Grannis, M.D., Palo Alto, California
Alvin J. Gross, M.D., San Francisco, California
David Hadley, M.D., Indianapolis, Indiana
Edwin Wayne Hakala, M.D., Fort Benning, Georgia
Howard William Halfman, M.D., Laconia, New Hampshire
George M. Hart, M.D., Minot, North Dakota
Felix Heimberg, M.D., Fitchburg, Massachusetts
Ned Barney Hein, M.D., Toledo, Ohio
David J. Henry, M.D., Dallas, Texas
Armand Hensas, M.D., Syosset, New York
Earl Pendleton Holt, Jr., M.D., St. Louis, Missouri
L. Thomas Hood, M.D., Omaha, Nebraska
John Crane Hoover, M.D., Hackensack, New Jersey
James J. Horvath, M.D., Detroit, Michigan
Kenneth Tower Hubbard, M.D., Oak Park, Illinois
Samuel Hammond Huff, Jr., M.D., Anderson, South Carolina
H. Ross Hume, M.D., Detroit, Michigan
William Jelier Hutchinson, M.D., Tallahassee, Florida
George William Hyatt, M.D., Bethesda, Maryland
Alfred Edison Jackson, M.D., Washington, D. C.
Melvin Howard Jahss, M.D., New York, N. Y.
Robert Morton Jameson, M.D., Santa Rosa, California
John Triplett Haxall Johnson, M.D., Baltimore, Maryland
Moulton K. Johnson, M.D., Santa Monica, California
Robert B. Johnson, M.D., Great Lakes, Illinois
Robert Rudolph Kessler, M.D., Columbus, Ohio

Richard Michael Kilfoyle, M.D., Boston, Massachusetts
Robert Franklin Kimbrough, M.D., Fort Wayne, Indiana
Herman Melvin Kunkle, M.D., Portsmouth, Virginia
Robert Noel LaMarche, M.D., Springfield, Massachusetts
Robert H. Lamb, M.D., Salt Lake City, Utah
Salvatore J. LaPilusa, M.D., Bayonne, New Jersey
John Danos Leidholt, M.D., Boston, Massachusetts
Philip O. Lichtblau, M.D., West Palm Beach, Florida
William Frank Lichtman, M.D., Hayward, California
Edwin Lindig, M.D., Jr., A.P.O. San Francisco, California
Douglas Twichell Lindsay, M.D., Fargo, North Dakota
William Carroll Lithgow, M.D., Aurora, Illinois
Robert C. Lockwood, M.D., Syracuse, New York
Paul A. Lovett, M.D., Wichita, Kansas
Frederick O. Mackel, M.D., Fort Wayne, Indiana
Melvin L. Makower, M.D., Berkeley, California
Anthony J. Marano, M.D., Buffalo, New York
Marvin Kenneth Margo, M.D., Oklahoma City, Oklahoma
Robert P. Meany, M.D., Chicago, Illinois
William Louis Meuleman, M.D., Lafayette, Louisiana
Marvin Harold Meyers, M.D., Inglewood, California
Richard Jasper Miller, Jr., M.D., Tampa, Florida
Robert Evans Miller, M.D., Charlotte, North Carolina
Wallace E. Miller, M.D., Indianapolis, Indiana
William Arthur Miller, M.D., Oklahoma City, Oklahoma
John Joseph Milligan, M.D., Houston, Texas
George Henry Millington, M.D., Chicago, Illinois
J. Garth Mooney, M.D., Seattle, Washington
James L. Moore, M.D., Raleigh, North Carolina
Joseph Paul Moreau, M.D., Edmonton, Alberta, Canada
Jack Moshein, M.D., Beverly Hills, California
Richard Donovan Mulroy, M.D., Brookline, Massachusetts
Allan M. McKelvie, M.D., Washington, D. C.
Francis Charles McMains, M.D., Baton Rouge, Louisiana
W. Robert McMurray, M.D., Portland, Oregon
Philip C. Nohe, M.D., Kansas City, Kansas
J. Richard Nolan, M.D., Ashtabula, Ohio
Francis Donal O'Brien, M.D., MacDill Air Force Base, Florida
Harry Wood O'Dell, M.D., Akron, Ohio
Eugene Gray Padel, M.D., Redding, California
Robert Warner Parvin, M.D., West Point, New York
Raymond J. Pellicore, M.D., Chicago, Illinois
Anthony Joseph Persico, M.D., Teaneck, New Jersey
Carl John Pessolano, M.D., Pittsburgh, Pennsylvania
Paul W. Phillips, M.D., LaCrosse, Wisconsin
Joseph L. Platt, M.D., Lynchburg, Virginia
Stanley John Pohlidal, M.D., Easton, Pennsylvania
Thomas C. Power, M.D., Great Falls, Montana
Robert Henry Ramsey, M.D., Dearborn, Michigan
R. Dee Robbins, M.D., Santa Rosa, California
Frederick William Rook, M.D., Arlington, Virginia
Howard Rosen, M.D., New York, N. Y.
Marvin P. Rosenberg, M.D., Passaic, New Jersey
William A. Scharffenberg, Jr., M.D., Los Angeles, California
Leo Thomas Schlenker, M.D., Kenosha, Wisconsin
George Philip Schneider, M.D., Lake Charles, Louisiana
Joseph R. Sgarlat, M.D., Kingston, Pennsylvania
Thomas O. Shindler, M.D., Houston, Texas
Merritt Butler Shobe, M.D., Kingsport, Tennessee
Edwin Caldwell Simonton, Jr., M.D., Shreveport, Louisiana
James E. Simpson, M.D., Burlington, Vermont
Charles G. Smith, M.D., Texarkana, Texas

William Earl Snell, M.D., Portland, Oregon
Burke M. Snow, M.D., Salt Lake City, Utah
Hyman R. Soboloff, M.D., New Orleans, Louisiana
George A. Sotirion, M.D., Springfield, Massachusetts
Sydney Coleman Sperling, M.D., Beverly Hills, California
Alvin Stander, M.D., Baton Rouge, Louisiana
Ernest Stich, M.D., New York, N. Y.
Harry Walter Stuermer, M.D., Alhambra, California
Hugh Leander Sulfridge, M.D., Saginaw, Michigan
Thomas Henry Taber, Jr., M.D., Phoenix, Arizona
Garvas S. Taylor, Jr., M.D., Norfolk, Virginia
Leroy Otten Travis, M.D., Tacoma, Washington
Arthur Warren Trott, M.D., Boston, Massachusetts
Loyd Roy Van Deventer, M.D., Wichita Falls, Texas
Jerome Waldman, M.D., Waukegan, Illinois
George William Waters, M.D., San Jose, California
Walter M. Watts, M.D., Asheville, North Carolina
William Gonder Weare, M.D., Niagara Falls, New York
Jerry W. Wedral, M.D., Berwyn, Illinois
William Stanley Weinkle, M.D., Miami Beach, Florida
Lawrence Milton Weisbrod, M.D., Allentown, Pennsylvania
George Wilbur Westin, M.D., Los Angeles, California
Kenneth R. Weston, M.D., Allentown, Pennsylvania
Paul Luther Weygandt, M.D., Akron, Ohio
Duane Alfred Broman Willander, M.D., Springfield, Illinois
Samuel D. Willens, M.D., Chicago, Illinois
Albert A. Wilson, M.D., Tampa, Florida
Douglas E. Wilson, M.D., Lawton, Oklahoma
Hudson Jennings Wilson, Jr., M.D., New York, N. Y.
Edwin Paul Woodward, M.D., San Diego, California
Richard A. Worsham, M.D., Jacksonville, Florida
Casimer A. Zarzecki, M.D., Miami, Florida

The next Annual Meeting of **The American Academy of Orthopaedic Surgeons** will be held at the Waldorf-Astoria Hotel in New York City, February 1 through 6, 1958.

THE ORTHOPAEDIC RESEARCH AND EDUCATION FOUNDATION

The Orthopaedic Research and Education Foundation is now receiving applications for research grants to be considered at its meeting in June 1957. All persons wishing to apply for grants are cordially invited to write for application forms to the Secretary, Dr. Harold Sofield, 116 South Michigan Avenue, Chicago 3, Illinois. Because of the excellent response of contributors, a sufficient amount of money has been received to make possible a significant number of additional grants. The final date for receipt of applications is June 1, 1957.

THE EXCHANGE FELLOWS

The Committee on Exchange Fellows of The American Orthopaedic Association have announced their selection of Fellows who will travel to Great Britain in 1957. The Fellows selected by the Committee and approved by the Executive Committee of The American Orthopaedic Association are the following:

Dr. Robert W. Bailey, University of California at Los Angeles Medical Center, Los Angeles 24, California;

Dr. Paul H. Curtiss, Jr., 2065 Adelbert Road, Cleveland 6, Ohio;

Dr. Edward D. Henderson, 200 First Street, S.W., Rochester, Minnesota;

Dr. J. William Fielding, 742 Park Avenue, New York 21, N. Y.

The Committee on Exchange Fellows of The Canadian Orthopaedic Association have selected Dr. Robert N. Lofthouse of Hamilton, Ontario, as their representative.

The five Exchange Fellows will leave New York on April 18 on the S.S. United States, reaching England in time to attend the Spring Meeting of The British Orthopaedic Association in Oswestry, May 9, 10, and 11. They will return on June 8 from Liverpool on the S.S. Parthia. The Presidents of both The American Orthopaedic Association and The Canadian Orthopaedic Association are inviting the Fellows to attend the annual meetings of their respective Associations during the last week in June.

THE AMERICAN BOARD OF ORTHOPAEDIC SURGERY

The Part I Examination of the American Board of Orthopaedic Surgery will be held on April 18 and 19 in Washington, D. C., St. Louis, Missouri, and Los Angeles, California.

The next Part II Examination for certification will be held January 29, 30, and 31, 1958, in New York City. The final date for receipt of application is August 15, 1957. Application should be made to the Secretary, Dr. Sam W. Banks, 116 South Michigan Avenue, Chicago 3, Illinois.

The **Fourth International Poliomyelitis Conference** of The International Poliomyelitis Congress will be held in Geneva, Switzerland, July 8 to 12, 1957. Correspondence and inquiries regarding the Conference should be addressed to the Secretariat of the Fourth International Poliomyelitis Conference, Hotel du Rhone, Geneva, Switzerland; telegraphic address, Inpolio, Geneva.

The **Seventh World Congress of the International Society for the Welfare of Cripples** will meet in London, England, from July 22 to 27, 1957.

The Ninth Annual Meeting of the **Association of Bone and Joint Surgeons** was held in Havana, Cuba, April 4 to 6, 1957.

The National Society for Crippled Children and Adults announce the publication (by the Blakiston Division of McGraw-Hill Book Company) of *Rehabilitation Literature, 1950–1955*. This volume, compiled by Earl C. Graham, Librarian, and Marjorie M. Mullen, Assistant Librarian, The National Society for Crippled Children and Adults, is a bibliographic review of the medical care, education, employment, welfare and psychology of handicapped children and adults. The price is $13.00.

AMERICAN MEDICAL ASSOCIATION

The Annual Meeting of the American Medical Association will be held in New York City, June 3 to 7, 1957. Meetings of the Section on Orthopaedic Surgery will be held on June 5 and 6. The following program has been arranged:

Wednesday, June 5, 9:00 A.M.

Closed Reduction of Common Shoulder and Elbow Dislocation without Anaesthesia.
Lt. Col. Robert W. Parvin, M.C., U.S.A., West Point, New York.
The Use of Local Anaesthesia in the Treatment of Fractures and Dislocations.
R. H. Ramsey, M.D., and H. E. Pedersen, M.D., Dearborn, Michigan.
Intramedullary "Pull-Out" Wire Fixation in Surgery of the Hand.
Lee J. Cordrey, M.D., Cleveland, Ohio.
Fractures of the Elbow in Children. A Review of 300 Cases.
John J. Fahey, M.D., and Donald J. Maylahn, M.D., Chicago, Illinois.
Treatment of Fresh Fractures of the Neck of the Femur with Intramedullary Stem Prostheses.
A. A. Savastano, M.D., L. A. Sage, M.D., and V. Zecchino, M.D., Providence, Rhode Island.
Ski Injuries.
Freeman D. Fowler, M.D., Idaho Springs, Colorado.

Thursday, June 6, 9:00 A.M.

The Occult Fractures.
Norman J. Rosenberg, M.D., and Rudolph S. Reich, M.D., Cleveland, Ohio.
Moderately Severe Whiplash Injuries of the Cervical Spine and Their Radiologic Diagnosis.
Martin S. Abel, M.D., San Francisco, California.
Fractures of the Distal Third of the Femur.
Marcus J. Stewart, M.D., and Sidney L. Wallace, Jr., M.D., Memphis, Tennessee.
The Care of the Infant with Dysplasia of the Hip.
Paul C. Colonna, M.D., Philadelphia, Pennsylvania.
Treatment of Fractures of the Os Calcis.
Morton H. Leonard, M.D., El Paso, Texas.

GORDON RESEARCH CONFERENCES

The Gordon Research Conferences for 1957 will be held from June 10 to August 30 at Colby Junior College, New London, New Hampshire, New Hampton School, New Hampton, New Hampshire, and Kimball Union Academy, Meriden, New Hampshire.

The Conferences were established to stimulate research in universities, research foundations, and industrial laboratories. This purpose is achieved by an informal type of meeting consisting of scheduled lectures and free discussion groups. Sufficient time is available to stimulate informal discussions among the members of a Conference. Meetings are held in the morning and in the evening, Monday through Friday, with the exception of Friday evening. The afternoons are available for recreation, reading, or participation in discussion groups as the individual desires. This type of meeting is a valuable means of disseminating information and ideas which otherwise would not be realized through the normal channels of publication and scientific meetings. In addition, scientists in related fields become acquainted and valuable associations are formed which result in collaboration and cooperative effort between different laboratories.

It is hoped that each Conference will extend the frontiers of science by fostering a free and informal exchange of ideas between persons actively interested in the subjects under discussion. The purpose of the program is not to review the known fields of chemistry, but primarily to bring experts up to date as to the latest developments, to analyze the significance of these developments, and to provoke suggestions as to underlying theories and profitable methods of approach for making new progress. In order to protect individual rights and to promote discussion, it is an established rule of each Conference that all information presented is not to be used without specific authorization of the individual making the contribution, whether in formal presentation or in discussion. No publications are prepared as emanating from the Conferences.

The first meeting of each Conference is held Monday morning at 9:00 A.M., Eastern Daylight Saving Time. The morning sessions, through Friday, are scheduled from 9:00 A.M. to 12:00 noon. The second session of each day is held in the evening from 7:30 to 10:00 P.M., Monday through Thursday. There are no Friday evening meetings.

Accommodations are available for a limited number of women to attend each Conference, also for wives who wish to accompany their husbands. All such requests should be made at the time of the request for attendance because these limited accommodations will be assigned in the order that specific requests are received. Children twelve years of age and older can be accommodated. Dogs or other animals will not be permitted in the dormitories.

Individuals interested in attending the Conference should request an application form from the office of the Director. Attendance at each Conference is limited to 100.

Requests for attendance at the Conferences, or for any additional information should be addressed to W. George Parks, Director, Department of Chemistry, University of Rhode Island, Kingston, Rhode Island. From June 10 to August 30, 1957, mail should be addressed to Colby Junior College, New London, New Hampshire.

GORDON RESEARCH CONFERENCE

CHEMISTRY, PHYSIOLOGY, AND STRUCTURE OF BONES AND TEETH

July 15 to 19, 1957

D. Harold Copp, *Chairman*, D. Dziewiatkowski, *Vice-Chairman*

Kimball Union Academy, Meriden, New Hamsphire

July 15:

Robert A. Robinson, *Chairman*. Fine Structure of Bones and Teeth.
Isidore Gersh. Fine Structure of Ground Substance.
William F. Neuman, *Chairman*.
M. J. Dallemagne. Nature of the Mineral of Bones and Teeth.

July 16:

Franklin C. McLean, *Chairman*. Parathyroids and Regulation of Blood Calcium.
Roy V. Talmage. Calcium Regulation in the Rat Studied by Intraperitoneal Lavage.
Gordon S. Stewart. The Role of Parathyroids in Calcium Homeostasis.
D. Harold Copp. Regulation of Blood Calcium in the Dog.
Wallace D. Armstrong, *Chairman*.
Bertil Lindquist. Studies on Calcium and Phosphorus Kinetics in Man.

July 17:

William P. Norris, *Chairman*. Radiostrontium Metabolism.
Cyril L. Comar. Comparison of the Biological Behaviour of Calcium and Strontium.
General Topics.
Harold C. Hodge, *Chairman*.
Selected Short Papers.
Hermann Lisco, *Chairman*.
Janet Vaughan. Radiation Effects on Bone.

July 18:

Ann Budy, *Chairman*. Effect of Hormones on the Skeleton.
Marshall R. Urist. The Transport of Calcium in the Blood of the Estrogenized Fowl.

July 18:

C. Willett Asling. Changes in Skeletal Tissues Induced by Pituitary Growth Hormone.
Isaac Schour. The Effects of Hormones on Teeth.
Edward C. Reifenstein, Jr., *Chairman*.
Charles E. Dent. Studies on Metabolic Bone Disease.

July 19:

Alexander B. Gutman, *Chairman*. Enzymes of Bone.
Subjects and speakers to be announced.

The **Ninth International Congress on Rheumatic Diseases** will be held at Toronto, Ontario, Canada, from June 23 to 28, 1957, under the auspices of the Canadian Rheumatism Association. All correspondence should be directed to: The Ninth International Congress on Rheumatic Diseases, Post Office Box 237, Terminal "A", Toronto, Ontario, Canada.

The Seventh Congress of the **International Society of Orthopaedic Surgery and Traumatology** will be held at Barcelona, Spain, from Monday, September 16 to Saturday, September 21, 1957.

Relatives of members, and doctors who are not members of the Society may attend on payment of a registration fee.

Requests for enrollment blanks and hotel room reservation blanks should be addressed to the Secretary General of the Society, Mr. A. Bailleux, 34 rue Montoyer, Brussels, Belgium, and must be returned to him before July 15, 1957. Hotel reservations will be secured by Thomas Cook and Son, official agent for the Congress, and confirmations will be sent by them to those attending the Congress. Air or steamship reservations and tickets may be purchased at any Thomas Cook office. Special reductions in fares will be available on French and Spanish railways at that time.

All sessions of the Congress will be held at the Palacio de Proyeccion in Montjuich, a suburb of Barcelona. A bus service will operate from the center of the city to the Palacio.

Monday's session, September 16, will open with a paper on "The Influence of Growth on the Sequelae of Bone and Joint Injuries" read by P. L. Chigot of France. It will be discussed by W. P. Blount (United States), B. McFarland (Great Britain), and J. Trueta (Great Britain). An open discussion will follow.

On Tuesday, September 17, "The Treatment of Flail Limbs" will be presented by G. Hohmann of Germany. The discussors will be M. Bastos-Ansart (Spain), and O. Scaglietti (Italy), and they will be followed by an open discussion.

There will be three symposia, two on Wednesday, September 18, "Giant-Cell Tumors and Their Treatment" and "The Surgical Treatment of Osteo-Arthritis of the Hip" and one on Thursday, September 19, "Causes and Treatment of Congenital Malformation of the Spine and Limbs". Friday's session (September 20) will be devoted to individual papers on miscellaneous specialized subjects, and to conclusions.

An active and interesting evening social program has been planned, and afternoons will be free for sightseeing. There will be organized trips to places of interest, including excursions to Montserrat, along the Costa Brava, and to a bullfight.

DETROIT ACADEMY OF ORTHOPAEDIC SURGERY

During the past Fall-Winter-Spring season the Academy was addressed by the following guest speakers: Dr. Joseph M. Janes of Rochester, Minnesota, who discussed Stimulation of the Longitudinal Growth of Legs by the Formation of Arteriovenous Fistula; Dr. Joseph E. Milgram of New York City, who spoke on

Muscle and Tendon Injuries, with special reference to implants prior to tendon transfer; Dr. William J. Schnute of Chicago, who presented the subject of Rehabilitation in Poliomyelitis; Dr. Henry Milch, New York City, who discussed Osteotomy of the Hip Joint; and Dr. David S. Grice of Boston, whose subject was Subastragalar Arthrodesis.

One of the monthly meetings was devoted to short presentations by members of the Academy and one of the meetings to presentations by orthopaedic residents of the Detroit hospitals.

The following officers were elected for the ensuing year: *President*, John M. Pendy, M.D.; *Vice-President*, Robert J. Bannow, M.D.; *Secretary-Treasurer*, James J. Horvath, M.D.

Three long-range research projects in rehabilitation will receive grants totaling $51,300 from the *Easter Seal Research Foundation* (The National Society for Crippled Children and Adults). Two of the projects will seek to improve the effectiveness of bone grafts in orthopaedic surgery.

Western Reserve University's grant of $29,400 will aid a five-year study conducted by Charles H. Herndon, M.D., Associate Professor of Orthopaedic Surgery, and Paul H. Curtiss, Jr., M.D., Assistant Professor of Orthopaedic Surgery. Called "Studies in the Immunological Factors in Homogenous Bone Transplantation", the work will seek to find if the formation of antibodies is the reason bones from donors do not graft as effectively in some patients as the patient's own bone.

A grant of $14,500 to the University of Mississippi will be used for a two-year investigation of the causes of inflammation which arise when donor bone is used in large bone transplants. The study is called "Histologic and Immunologic Investigations of Homogeneous-Bone Transplants".

Medical Education Week will be observed again this year April 21 to 27. Its purpose is to bring to the public the story of the dramatic progress of medical schools in the United States, and to emphasize their contribution to the nation in supplying doctors, in research, and in professional and community services. Medical Education Week can be successful if all physicians and medical personnel will help to promote it. For further information write to Leo E. Brown, Director of Public Relations, American Medical Association, 535 North Dearborn Street, Chicago 10, Illinois.

ADDENDUM

In the Proceedings section of the January 1957 issue of The Journal, Vol. 39-A, page 227, in the summary of "Spondylolisthesis, A Review of Seventy-Three Patients Treated by Arthrodesis of the Spine" by Dr. George Hammond, Dr. Robert E. Wise, and Dr. G. Edmund Haggart, the second sentence of the concluding paragraph should be amplified to read: "If conservative therapy fails and if there is no evidence of radiculitis in either lower extremity, successful arthrodesis of the spine alone should bring about an excellent result. In those patients having radiculitis preoperative myelography, removal of the loose neural arch, nerve-root decompression, exploration for protruding intervertebral disc, and arthrodesis would seem to be the wisest surgical treatment to minimize the occurrence of postoperative radicular pain."

Book Reviews

THE PRINCIPLES AND ART OF PLASTIC SURGERY. Sir Harold Gillies, C.B.E., F.R.S., and D. Ralph C. Millard, Jr., M.D. Boston, Little, Brown & Company, 1957. Two volumes, $35.00.

Sir Harold Gillies, the senior author of *The Principles and Art of Plastic Surgery*, has been described as "puckish" by Jerome Webster in the introduction to this two-volume, unique autobiography of one of the world's renowned plastic surgeons. This perplexing puckishness is a disarming feature of the book, one which at first seems out of keeping, but as one delves into the chapters more carefully, searching for the real meat which they contain in abundance, one is charmed rather than offended.

This book can be considered neither a true reference work nor a textbook, but rather a story of Sir Harold and the establishment of plastic surgery as a recognized specialty. There is no bibliography. The reader must refer to other works for original sources. There are no legends. Instead, the reader must compare the sequence of pictures in the margins of each page with the stories recounted in the immediately adjacent text. By telling the life story of each of the patients who have sought his help because of war wounds, civilian injuries, congenital anomalies, or disease, Sir Harold has written not only an account of great plastic surgical achievements but a very human story.

To all plastic surgeons, and particularly to those who served in World War II, the story of the development of plastic surgery at the Cambridge Hospital in Aldershot will be informative and reminiscent. Many ideas taken for granted today were formulated here: the principle of face-down position in the transportation of those seriously wounded about the mouth and jaws, the important pioneering achievements of Magill in devising apparatus and techniques for administration of anaesthesia during surgery about the mouth, the development of bone-grafting for replacement of missing segments of the mandible, the rediscovery of the usefulness of local flaps, cooperation between the plastic surgeon and the dentist, and finally, and perhaps most important of all, the development of the tubed-pedicle method of skin transplantation which, thanks to Gillies and his host of students, is now standard throughout the world.

Surgeons on this side of the Atlantic will be conscious of differences between British and American methods. Most American contributions, thanks to the development and refinement of techniques for the securing of free skin grafts, have been concerned with the use of these grafts in repairs. Sir Harold exemplifies the British approach using local tissue and remote flaps. The American methods are more direct and consequently more rapid, but the more cumbersome, prolonged, yet ingenious use of multiple remote flaps or multiple shifting of local flaps promises end results which are hard to match with free skin grafts. The surgeon who studies the "Flap Happy" chapters will be amazed at the varieties of methods of shifting tissue which are illustrated, and proud that surgery can offer so much. Gillies questions the reluctance of American surgeons to use the forehead in nose reconstruction and the military directive of World War II that the arm should be used by preference for military casualties. It is doubtful whether disfigurement of the forehead can be concealed even in the hands of our most expert British colleagues. The British persist in the use of external fixation (headcaps, guy wires, struts, and pins) in the support of facial fractures — methods which are being supplanted in the United States by direct internal fixation. Finally, even the name of the troublesome projection at the end of a scar differs on the two sides of the Atlantic, pig's ear *versus* dog's ear.

This unconventional book will no doubt be read by many generations of surgeons interested in the principles and art of plastic surgery. There is much to be learned from one of the few surviving pioneers and teachers who has sought throughout his lifetime to solve the major problems of repair and at the same time to satisfy the yearnings of each patient for a more nearly perfect or natural appearance. Many stimulating and worth-while hours can be spent reading the text, studying the illustrations, and allowing one's imagination to reconstruct the planning and the steps whereby each result was achieved.

Bradford Cannon, M.D.

SURGERY IN WORLD WAR II. ORTHOPEDIC SURGERY IN THE EUROPEAN THEATER OF OPERATIONS. Mather Cleveland, M.D. Washington, Office of The Surgeon General, Department of the Army, 1956. $4.00.

It is hard to realize that the methods which today form the basis of the successful surgical management of open wounds had been developed and proved by the close of the First World War. Wide incision to provide free access to the depths of the wound, free excision of all devitalized tissue, scrupulous hemostasis, removal of foreign bodies, immobilization, and, wherever possible, preservation of fragments to assure ultimate bone continuity were known, toward the end of the War, to a few, very competent high-ranking medical officers. These measures as well as wound closure by primary suture, delayed primary suture or secondary suture, used in conjunction with competent management of the fracture, had been proved in adequate series of battle casualties. Knee-joint wounds had been managed by thorough débridement, immediate closure of the joint capsule, and delayed primary closure of the superficial tissues. These techniques and the principles upon which they are based were never in general use in that conflict; the War was over before they were established throughout the military hospitals — indeed, before they appeared in the medical literature. They were, however, recorded in the official medical histories of World War I, both British and American.

Comparatively little attention was paid to these methods in the years which followed. It was not until well into the Second World War, and at a high price in life and limb, that these lessons, learned at the close

of the First World War and then forgotten, had been relearned, and successful war-wound management was put into practice on a large scale.

Battle injuries of the extremities with the inevitably high incidence of extensive bone and joint involvement comprised two-thirds of the more than 380,000 casualties in the European Theater alone. The orthopaedic care of all these wounded, over a vast terrain and often under rapidly changing conditions, was a tremendous undertaking. The responsibility was met superbly. To the author, formerly Senior Consultant in Orthopaedic Surgery, European Theater of Operations and Colonel, Medical Corps, Army of the United States, is due a large part of the credit for the high orthopaedic achievement which was attained. We are further indebted to him for this lucid recording of the orthopaedic experience in this theater. How the work was divided, the medical personnel organized, and methods of management developed, perfected, and put into use throughout the Theater has been told in this book with consummate clarity, force, and completeness.

Part I is devoted to administrative organization and Part II to clinical policies and practices; both are by Dr. Cleveland. In Part II are plainly set forth the lessons, the errors, and the successes of this vast experience. They are of tremendous significance — almost as much today in a highly mechanized peacetime society as in those many months of combat. Included are chapters devoted to initial and reparative wound surgery, techniques of fracture management, regional injuries, amputations, resuscitation and supplemental therapy, chemotherapy and antibiotic therapy. Also discussed are postoperative complications, rehabilitation, and non-combat lesions. Part III is concerned with special types of bone and joint injuries, including complete dislocation of the acromioclavicular joint, battle-incurred compound fractures about the hip joint, jeep injuries of the hip joint. Part III is by Dr. Cleveland with Dr. Marshall Urist as co-author.

The volume is carefully edited, handsomely put together, and well illustrated. This book belongs in the library of every surgeon.

William A. Rogers, M.D.

THE SPINE: ANATOMICAL RADIOGRAPHIC STUDIES. Development in the Cervical Region. Lee A. Hadley, M.D. Springfield, Illinois, Charles C. Thomas, 1956. $6.50.

This monograph is an important contribution to the understanding of roentgenographic studies of the cervical spine. The author has combined his extensive experience in roentgenology with anatomical studies on the cadaver to present an unusually clear and concise description of the developmental, congenital, traumatic, and degenerative abnormalities of the cervical spine that may be visualized by roentgenographic techniques.

The monograph is brief, it is beautifully illustrated, and it correlates the anatomical changes with those present in the roentgenogram. Precise instructions are given regarding techniques for obtaining roentgenograms that will be satisfactory for study of the cervical spine.

The first three sections of the book, dealing with the embryology, the development, and the congenital anomalies of the cervical spine, give a background of information which affords a better understanding of many abnormal changes encountered in roentgenographic studies of this area. Particularly well done is the section on congenital anomalies.

A complete discussion of trauma to the cervical spine is not attempted, but the more obscure lesions such as whiplash injuries, traumatic subluxation, and ligamentous injuries are described and illustrated in some detail. The degenerative changes that involve the intervertebral discs, the articulations, and the vertebral bodies with resulting spurring, encroachment upon intervertebral foramena, and the effect of these changes upon the physiology and mobility of the cervical spine are illustrated by correlating roentgenographic findings with gross anatomical and histological studies. The illustrations with the excellent captions are particularly valuable. Many of the reproductions are retouched to emphasize the pathology involved.

Accurate interpretation of roentgenograms of the cervical spine is often difficult, and the material presented in this short monograph will be of real help and interest to all orthopaedists.

Charles H. Herndon, M.D.

JOINT LIGAMENT RELAXATION TREATED BY FIBRO-OSSEOUS PROLIFERATION. With Special Reference to Low Back Disability, Trigger Point Pain, and Referred Pain. George Stuart Hackett, M.D. Springfield, Illinois, Charles C. Thomas, 1956. $4.75.

The method of treatment presented and the claims made in this book lack the necessary clinical and scientific substantiation to justify its publication. The book is not recommended.

William A. Rogers, M.D.

INSTRUCTIONAL COURSE LECTURES, Vol. XIII, The American Academy of Orthopaedic Surgeons. R. Beverley Raney, M.D., Editor. Ann Arbor, J. W. Edwards, 1956. $12.00.

The 1956 volume of the Instructional Course Lectures adds twenty-seven to the 303 lectures which have been published in this series since 1949, when the present method of presentation was adopted. The publishers list all of these volumes as available. Together they offer 340 hours of teaching in orthopaedics by an all-star faculty, more than is offered by many of our medical schools. Verbum sat sapienti.

J. A. R.

OPERATIVE ORTHOPAEDICS AND TRAUMATOLOGY (Title in Bulgarian). B. Boytchev, B. Conforty, and K. Tchokanov. Sofia, State Publication, Science and Art, 1955.

Operative Orthopaedics is a large book of 656 pages, written in Bulgarian, which is somewhat related to the Russian language. There are 590 illustrations, consisting of fairly satisfactory line drawings, moderately clear half tones, and plates of good quality. The binding and paper are good.

The book is a complete treatise on orthopaedic surgery and is divided into two parts: general and special. In the first part, the general section, fundamental principles are considered. Various surgical methods of resection, fixation, and elongation of bone are discussed. Plastic procedures, tendon surgery, operations on muscle and joints are described. There is much reliance on the great surgeons of the Nineteenth Century. Techniques of resuscitation, treatment of shock, hemorrhage, organization of operating rooms, instrumentation, anaesthesia, amputations, resections, treatment of fresh wounds, and the like are all included. The influence of the classic works of the great Farabeuf is felt here.

In the second part are treated, in accordance with anatomical divisions, the neck, clavicle, scapula, shoulder, arm, elbow joint, forearm, hand, pelvis, hip joint, thigh, knee, leg, foot, spinal column, and ribs.

The text is of great interest and reflects an apparently vast experience of the authors. Many references to familiar American orthopaedic authorities, as well as to authorities from other countries, are found. A number of procedures of Russian surgeons and some original methods by the authors are described. As an illustration of the last, there is a description of Boytchev's method of treating recurrent dislocation of the shoulder. The origin of the short head of the biceps, the coracobrachialis, and a portion of the pectoralis minor are osteotomised from the coracoid process; they are then passed behind the musculotendinous portion of the subscapularis and reattached to the coracoid process under tension.

A balanced presentation of surgery of the hand is given. A number of muscle-transplantation operations are described for the upper and lower extremity. Most of them are well known in the United States. It is surprising to find descriptions of many procedures which add to the encyclopedic character of this treatise, but which are not frequently used by American orthopaedic surgeons. In the section on the hip joint, the senior author describes a method of hip reconstruction. The necrotic femoral head is removed. A large fragment of the greater trochanter and subjacent area of the shaft is osteotomised in the coronal plane, moved into the acetabulum, and then transfixed to the remaining part of the trochanter. Thus, a substitute for the neck of the femur is created.

It is impossible to even mention in a short review many of the original methods for various conditions which are described.

It may be stated that, generally, the book is interesting and instructive. It is regrettable that its language makes it inaccessible to most American readers.

Emanuel Kaplan, M.D.

PROCEEDINGS. SECOND INSTITUTE ON REHABILITATION CENTERS. Chicago, National Society for Crippled Children and Adults, 1956. $1.00.

This brochure contains ten papers presented at the Second Institute of Rehabilitation Centers which highlight the functions of the members of the rehabilitation team in dealing with social and emotional problems.

J. A. R.

THE STRESS OF LIFE. Hans Selye, M.D. New York, McGraw-Hill Book Company, Inc., 1956. $5.95.

This book tells in language understood by layman and scientist alike, what medical research has learned about the nature of stress, how our bodies react to the wear and tear of living, and what we can do to adjust to this depletion of our adaptive energy. Stress is discussed in relation to various diseases—cardiovascular disease, digestive disorders, inflammatory diseases, mental derangements, hypertension, and others.

Dr. Selye, in his preface, points out that the book proceeds logically from the discovery of stress to the analysis of its mechanism in health and disease, and explains how this knowledge could further our understanding of life, in theory and in practice.

He writes informally about his now-famous concept of stress, and with keen understanding of human nature. He denies that he is a philosopher, yet his chapter, "Philosophic Implications", is unexpectedly thoughtful and satisfying, and is as stimulating as the rest of this absorbing book.

The book is illustrated by drawings and by photographs; there is a glossary of technical terms and an excellent index.

L. H.

MODERN TRENDS IN ORTHOPEDICS (Second Series). Edited by Sir Harry Platt, LL.D., M.D., M.S., F.R.C.S., F.A.C.S. New York, Paul B. Hoeber, 1956. $12.50.

This Second Series of Modern Trends in Orthopedics has brought up-to-date the concepts of a number of leading authorities on eleven subjects. This is not a revision of the First Series as many new subjects have been added and more detail has been given to some similar topics.

The editor, Sir Harry Platt, has had a very extensive experience with congenital dislocation of the hip, and from this material has given "reason for sober satisfaction" with the closed method of reduction for this condition.

There is an excellent section on Pott's paraplegia by H. J. Seddon. His various steps in the techniques of anterolateral decompression and of costotranversectomy should be studied by all who have to deal with this situation.

F. W. Holdsworth has covered the subject of traumatic paraplegia from all its many aspects—including nursing care and bladder management. In this country fracture-dislocation in the thoracolumbar area of the spine with neurological involvement is treated by decompressive laminectomy and internal fixation with bone grafts.

Mr. J. C. Scott has contributed a chapter on displacement of the upper epiphysis of the femur, approaching it under heading of cervical coxa vara and "adolescent coxa vara", in both cases emphasizing the importance of early diagnosis. He cites typical cases and outlines his very reasonable treatment.

A very well illustrated chapter by Mr. R. Guy Pulvertaft deals with contractures of the hand and points out the indications for use of the various accepted corrective methods.

Norman Capener has written a thoughtful article on the mechanics in reconstructive surgery of the hip.

Each contribution is well documented. I believe this Second Series will be even more valuable than the First.

J. G. Petrie, M.D.

Pott's Paraplegia. D. L. Griffiths, H. J. Seddon, and R. Roaf. London, Oxford University Press, 1956. $12.75.

This book presents the most complete coverage of Pott's paraplegia to date that we have encountered. An intensive review of 175 cases of paraplegia incident to tuberculosis of the spine seen by one of the authors (H. J. S.) has been made. To this series have been added fifty-three cases seen by the other two co-authors. Even though one considers that the period of study began in 1931, this represents a formidable amount of material for review.

A painstaking dissection of this mass of material has been made. There are numerous and excellent illustrations, such as roentgenograms, tables, and line drawings. Full advantage has been taken of the material and the study extended in every possible direction. Historical reference is carried out in a most interesting manner as to previous knowledge on this subject.

Pathogenesis is excellently portrayed. Dural pressure may be due to abscess or bone displacement, causing narrowing of the vertebral canal. The authors' statements of fact are well documented and illustrated. On the basis of the pathological changes, the authors justifiably discuss the relative merits of laminectomy, posterolateral exploration, and anterolateral decompression. Furthermore, they present fifty consecutive cases of anterolateral decompression. Considering the disastrous potentials present in such cases, the results will prove astounding to those less acquainted with the possibilities of recovery of the spinal cord from such pressure lesions. The descriptions of operative procedures indicated are adequately made and well illustrated. They acknowledge that each case may present its own problems and that minor variations in technique, depending upon the situation found, may prove necessary.

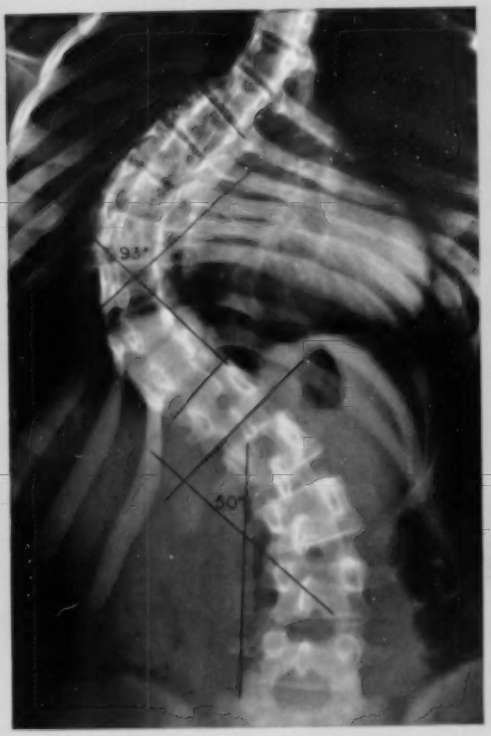
One may regret that more emphasis is not placed upon the necessity of solid posterior fusion for support before anterior débridement is done. Likewise, one could wish that the authors could have noted that, with solid posterior fusion secured, abscesses recede together with extradural pressure and that most such cases, adequately fused, permanently recover without necessity of anterior decompression.

Despite this, their treatise has been factual, exceedingly honest, and represents a monumental step forward in the understanding and care of patients with these lesions. For those of us exposed to the necessity of caring for people with such palsies, availability of their material in book form for study and careful appreciation is certainly most worth while. The present reviewer is deeply thankful to them for the tremendous effort that has gone into the preparation of this monograph.

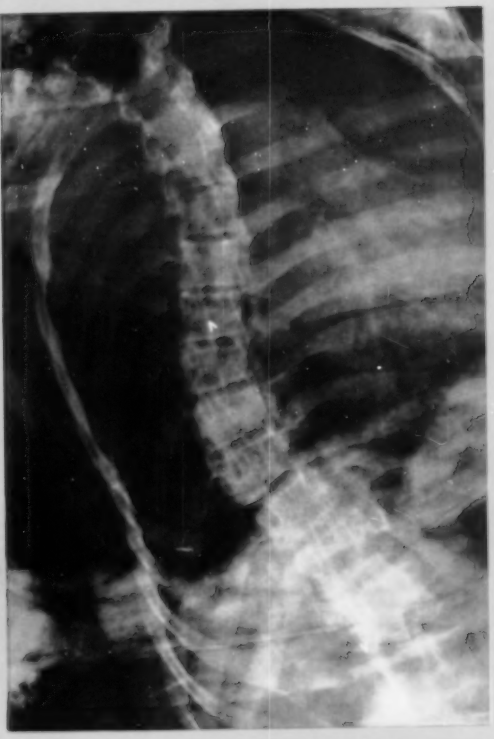
David M. Bosworth, M.D.

Radiographs and photographs like these

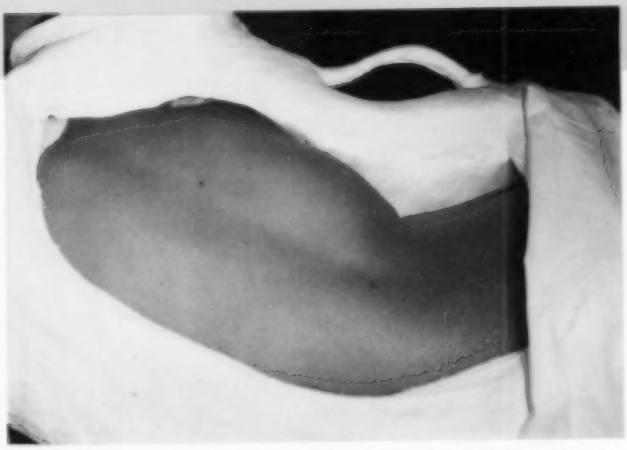
are invaluable – to the attending physician – to teachers and students!



1. **CASE:** 14-year-old girl with idiopathic scoliosis. Precorrection radiograph with patient seated.



2. Postcorrection radiograph with patient in plaster jacket following spinal fusion (top and bottom of the fusion marked by metallic clips).



3. Right dorsal curve has been corrected in plaster turnbuckle jacket and back is seen exposed through window. Methylene blue tattoo marks identify area of vertebral column to be fused. *Steps in surgery shown on page following.*

Here you see a trend. With the visual data reproduced on these pages, the physician can review his case, discuss it in detail with associates and students.

In addition to its value in discussion and teaching, material such as this may be

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TRADEMARK

used to illustrate medical papers and exhibits: it is invaluable as a basis for research—today, tomorrow, years later.

The cost is low, compared with the value of a fully documented case record.

For Radiography: Kodak Blue Brand X-ray Film and Kodak x-ray processing chemicals meet the most exacting requirements. They are always dependable—uniform. Quality-controlled—rigidly tested—they are made to work together.

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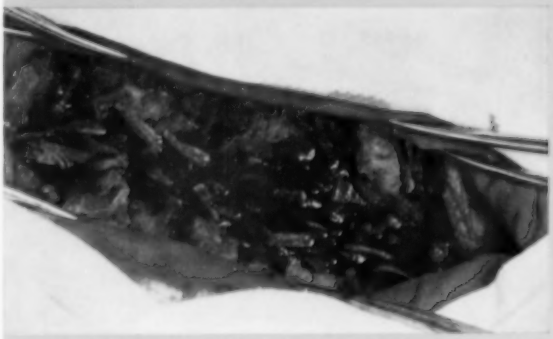
Order x-ray products from your x-ray dealer, photographic products from your photographic dealer.

EASTMAN KODAK COMPANY
Medical Division
Rochester 4, N. Y.

Kodak
TRADE MARK

4. Posterior elements of the vertebrae to be fused have been exposed by subperiosteal dissection.



5. Interdigitation of bony spicules across the interlaminal spaces has been completed.

6. Raw bony area is reinforced by slivers of cancellous bone obtained from the bone bank.

7. Incision closed.

TRADEMARK

Something New from Kalamazoo!

the Stryker PLASTERVAC

Another new Orthopedic Frame development — the Stryker PlasterVac. This heavy duty vacuum combines with the Stryker Cast Cutter to eliminate messy plaster dust and cut clean-up time in half . . . a necessity in every plaster room!

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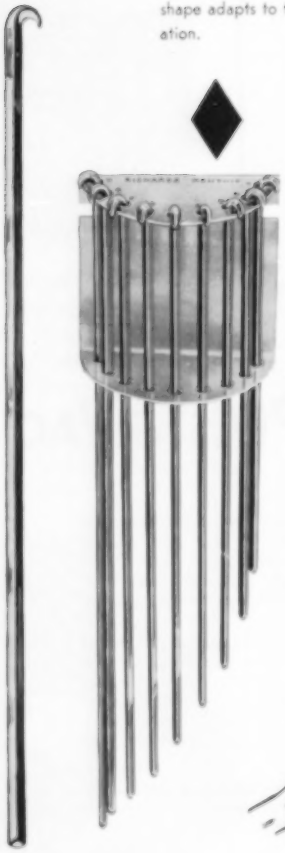
Richards DIAMOND INTRAMEDULLARY PINS

SMO STAINLESS

Richards diamond intramedullary pins offer the surgeon an aid in the prevention of rotation of fragments.

Flexible in the minor diameter, yet rigid in the major diameter, the diamond cross-sectional shape adapts to the contour of the intramedullary canal, yet provides excellent internal fixation.



PRICE PER SET INCLUDES ALUMINUM RACK

No. 203 Set 7mm x 9mm diameter pins for the FEMUR.

9 pins from 11" to 17" $67.50

Individual pins as follows ..... each 7.50

A	B	C	D	E	F	G	H	I
11"	11¾"	12½"	13¼"	14"	14¾"	15½"	16¼"	17"

No. 204 Set 4mm x 6mm diameter pins for TIBIA, HUMERUS AND LOWER THIRD OF FEMUR.

9 pins from 8" to 14" $54.00

Individual pins as follows ..... each 6.00

A	B	C	D	E	F	G	H	I
8"	8¾"	9½"	10¼"	11"	11¾"	12½"	13¼"	14"

No. 205 Set 3mm x 5mm diameter pins for HUMERUS.

9 pins from 8" to 14" $54.00

Individual pins as follows ..... each 6.00

A	B	C	D	E	F	G	H	I
8"	8¾"	9½"	10¼"	11"	11¾"	12½"	13¼"	14"

No. 206A Set 3mm x 5mm diameter pins for RADIUS AND ULNA.

13 pins from 4" to 10" $52.00

Individual pins as follows ..... each 4.00

A	B	C	D	E	F	G	H	I	J	K	L	M
4"	4½"	5"	5½"	6"	6½"	7"	7½"	8"	8½"	9"	9½"	10"

No. 206B Set 2mm x 3mm diameter pins for RADIUS AND ULNA.

13 pins from 4" to 10" $52.00

Individual pins as follows ..... each 4.00

A	B	C	D	E	F	G	H	I	J	K	L	M
4"	4½"	5"	5½"	6"	6½"	7"	7½"	8"	8½"	9"	9½"	10"

No. 207 Set 2mm x 3mm pins for PHALANGES AND SMALL BONES.

13 pins from 1" to 4" $26.00

Individual pins as follows ..... each 2.00

A	B	C	D	E	F	G	H	I	J	K	L	M
1"	1¼"	1½"	1¾"	2"	2¼"	2½"	2¾"	3"	3¼"	3½"	3¾"	4"

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FOR EITHER ROUND OR DIAMOND PINS

Anodized aluminum to prevent scratching or nicking pins. Thumb screw holds pin in place to gently introduce pin by hand. Not to be used as a driver. One size, 3/16" slot, takes any round pin 3/16" D. or smaller, and both the 2mm x 3mm and 3mm x 5mm diamond pins.

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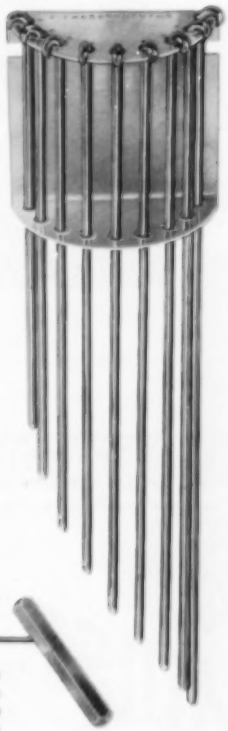
Richards ROUND INTRAMEDULLARY PINS

SMO STAINLESS



Richards round intramedullary pins are carefully formed of selected SMO Stainless of a special temper to give proper resiliency.

Bending irons may be used to pre-shape pin, if desired.

The bullet-nose end of the pin helps to prevent breaking through the cortex, and smoothly guides the pin down the intramedullary canal.

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No. 262 Set 5/16" diameter pins for Humerus and Tibia

9 pins from 8" to 14" $54.00
Individual pins as follows 6.00

A	B	C	D	E	F	G	H	I
8"	8¾"	9½"	10¼"	11"	11¾"	12½"	13¼"	14"

No. 263 Set ⅛" diameter pins for Radius and Ulna.

13 pins from 4" to 10" $52.00
Individual pins as follows ..... each 4.00

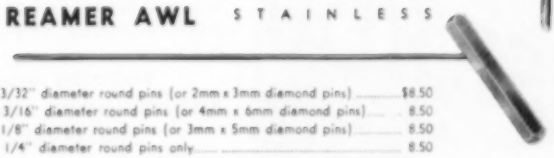
A	B	C	D	E	F	G	H	I	J	K	L	M
4"	4½"	5"	5½"	6"	6½"	7"	7½"	8"	8½"	9"	9½"	10"

No. 264 Set 3/32" diameter pins for Phalanges, etc.

13 pins from 1" to 4" $26.00
Individual pins as follows ..... each 2.00

A	B	C	D	E	F	G	H	I	J	K	L	M
1"	1¼"	1½"	1¾"	2"	2¼"	2½"	2¾"	3"	3¼"	3½"	3¾"	4"

REAMER AWL STAINLESS



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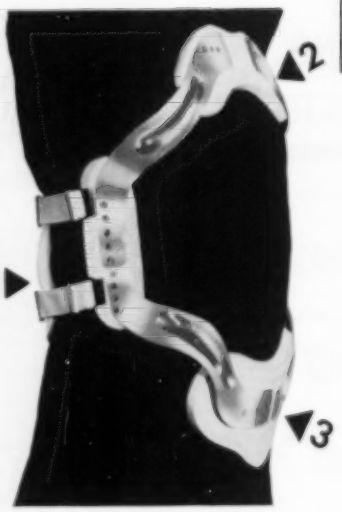

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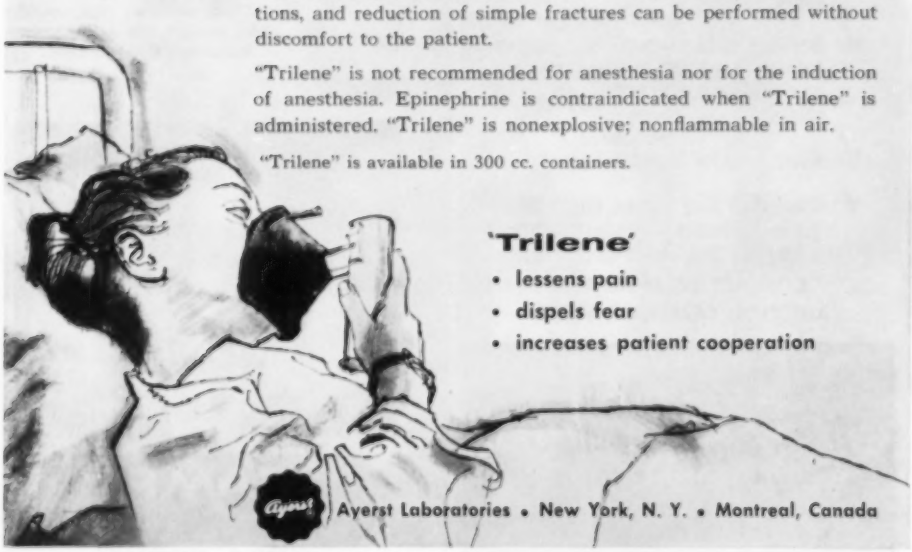

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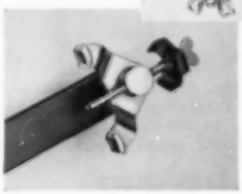

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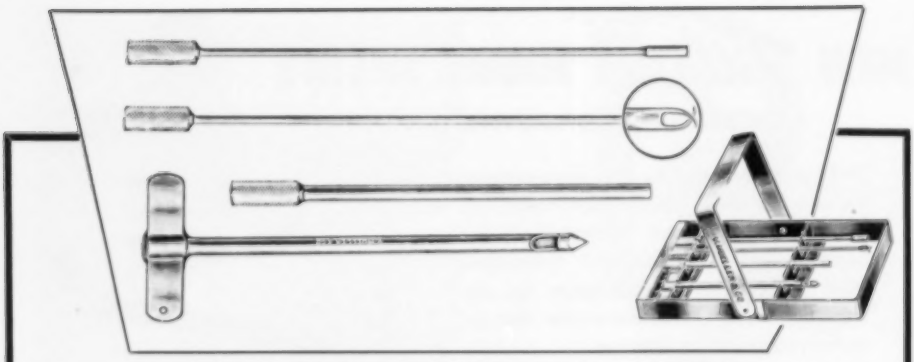

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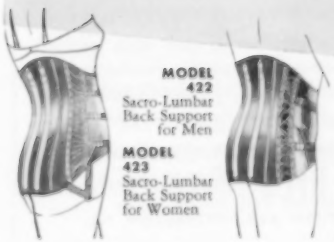

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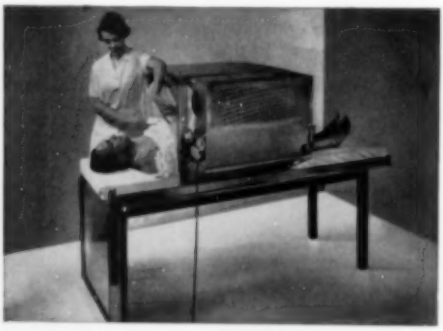

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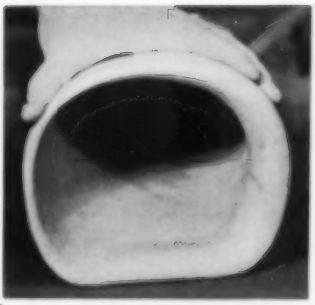

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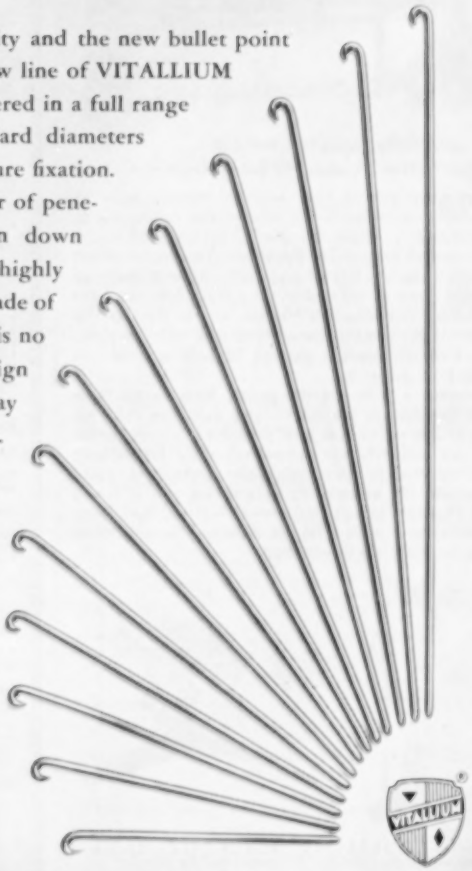

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